# Performance Summary of Anchorage's Asplund Water Pollution Control Facility & Cook Inlet Water Quality

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## Summary of Findings

The performance of Anchorage's John M. Asplund Water Pollution Control Facility (WPCF) over the past 20 years has been excellent. This facility has been operated to meet effluent limits and requirements specified in the NPDES permit and 301(h) Waiver issued by the United Stated Environmental Protection Agency. The Asplund WPCF treatment process achieves removal rates that are much higher than typical primary treatment facilities, and higher than typical advanced (chemical) primary treatment.

The Knik Arm of Cook Inlet provides rapid mixing and dispersion of wastewater discharged by Anchorage's waterwater treatment facility into the marine waters off Point Woronzof. The discharge itself contains very low concentrations of metals or organic materials and meets all discharge requirements and water quality criteria. Extensive monitoring in Knik Arm has found no evidence of any impact of the discharge on the chemical or biological characteristics of Cook Inlet. Particulate metals levels in Knik Arm are almost solely the result of natural glacial scour associated with riverine input are not the result of any human activity. Dissolved metals concentrations in Knik Arm are similar to background open ocean concentrations. Bioassays have shown that the Point Woronzof discharge is not toxic even at the minimum dilutions achieved within its zone of initial dilution.

Monitoring and research studies have not shown any impact of the Asplund WPCF discharge on the area's biological resources, including marine mammal populations. The discharge has not caused warnings, restrictions, or closures: and there is no evidence that the discharge has caused any mortalities in fish or marine mammal populations. Bioaccumulation surveys have documented no accumulation of mercury in potential Beluga whale foods (salmon and saffron cod) or in Beluga whales in Knik Arm.

# Introduction

The Anchorage Water and Wastewater Utility (AWWU) understands that the National Marine Fisheries Services has initiated a status review for the beluga whales inhabiting Cook Inlet to determine if they should be listed under the Endangered Species Act (ESA). This technical memorandum has been developed to provide the National Marine Fisheries Service (NMFS) with a summary of the performance of Anchorage's John M. Asplund Water Pollution Control Facility (WPCF) over the past 20 years. This document reviews the AWWU treatment facility and discharge system, the NPDES permit, NPDES monitoring program, the receiving water environment, effluent quality and treatment performance, and it provides a review of the results of the extensive monitoring program conducted in Cook Inlet over the past 20 years.

This document provides pertinent information on the Municipality of Anchorage's municipal sewage discharge into Cook Inlet including information on the effluent quality, receiving water and sediment quality, biological communities, and bioaccumulation studies that are specifically relevant to beluga whales. AWWU discharges primary-treated municipal wastewater into Cook Inlet at Point Woronzof. This discharge is authorized by an NPDES permit and 301(h) Waiver issued by the United Stated Environmental Protection Agency (EPA) Region 10, and approved by state and federal resources agencies. The NPDES permit includes extensive effluent monitoring, as well as extensive physical, chemical, and biological monitoring of the receiving waters. This comprehensive monitoring program has been actively documenting Asplund WPCF wastewater performance and receiving water conditions in Cook Inlet since 1986.

# Treatment, Discharge, Permits & Monitoring

## Treatment Facility and Discharge System

The Asplund WPCF serves the Anchorage area and is located at Point Woronzof (Figure 1). Plant influent is primarily of domestic origin, although a limited industrial component is included and the Municipality of Anchorage has local limits for pretreatment and a monitoring program. There are no combined sewers in the Anchorage sewer system. The existing facility provides treatment for a design average flow of 58 mgd and a maximum hourly flow of 154 mgd, and the annual average daily discharge is approximately 28 mgd.

Existing treatment units provide screening, grit removal, sedimentation, skimming, and chlorination. The treatment process gets high removal rates that are much higher than typical primary treatment facilities, and higher than typical advanced (chemical) primary treatment. Sludge from the primary clarifiers is thickened and dewatered. The dewatered sludge and skimmings are incinerated and the ash disposed of in a sanitary landfill.

Chlorinated primary effluent is discharged through a 120-inch diameter chlorine contact tunnel and then through an 84-inch diameter outfall to to Knik Arm of Cook Inlet (Figure 2). The Point Woronzof outfall extends 804 feet from the shore at Point Woronzof and terminates as a trifurcated diffuser. The discharge depth of the diffuser during the typical 24-hour tidal cycle studies ranges from 12 feet to 41 feet. The outfall diffuser has a defined zone of initial dilution (ZID) that is a radius of 650 meters from a point 30 meters inshore of the terminus, and the ZID is the region provided for immediate mixing and dilution of the wastewater (Figure 3). Current speeds at the discharge site range from approximately one to six knots. Details of the tidal-driven currents, discharge plume transport, and dilutions at the discharge site are reviewed in a later section of this document.

## Permits and Site Specific Criteria

The AWWU operates the Asplund Water Pollution Control Facility (WPCF) under NPDES Permit No. AK-002255-1, as issued by EPA Region 10 in 2000.

As part of renewal application for the NPDES permit in 1999 (CH2M HILL, 1998), AWWU also submitted an application for a Site Specific Water Quality Criteria (SSWQC) to the Alaska Department of Environmental Conservation (ADEC) for a limited area of the Upper Cook Inlet in the vicinity of Point Woronzof (CH2M HILL, 1999). The justification for incorporating SSWQC for the Point Woronzof area into the Alaska State Water Quality Standards included the following key elements:

- High ambient turbidity and non-dissolved metals concentrations in Knik Arm of Cook Inlet result from upstream watershed processes and these represent high natural levels of turbidity and non-bioavailable metals fractions; and
- Site Specific Water Quality Criteria uses the natural levels of turbidity and EPA's metals policy of applying only the dissolved metals fraction as potentially bioavailable and appropriate for the protection of aquatic life, human health, and beneficial uses in the waters.

*The Site Specific Water Quality Criteria (SSWQC) were deemed appropriate and were approved by EPA, ADEC and NMFS, because the natural background concentrations of non-dissolved metals (non-bioavailable) and turbidity in Cook Inlet* were higher than the non-dissolved metals-based criteria and turbidity standards that were in effect in the Alaska Water Quality Standards in 1999. The SSWQC for acute and chronic chemical criteria (dissolved metals and turbidity criteria) for the Point Woronzof area were incorporated into Alaska Water Quality Standards, 18 AAC 70.236(b)(4).

EPA's reissuance of the Asplund WPCF NPDES permit and EPA's approval of the SSWQC required EPA to prepare a Biological Evaluation to assess any potential effects on threatened or endangered species. This Biological Evaluation (U.S. EPA, April 2000) concluded that reissuance of the NPDES Permit and approval of the site-specific criteria for upper Cook Inlet would not adversely affect beluga whales. The EPA also prepared an Essential Fish Habitat (EFH) Assessment (U.S. EPA, June 2000), in accordance with the Magnuson-Stevens Fishery Conservation and Management Act, and this EFH concluded that reissuance of the NPDES Permit and approval of the site-specific criteria for upper Cook Inlet would not adversely affect EFH in the region. In a June 2000 letter to EPA, the National Marine Fisheries Service concurred with both EPA's Biological Evaluation and EFH Assessment conclusions (NOAA, June 2000).

In recent years after the approval of the SSWQC for the Point Woronzonf area in 2000, the Alaska Water Quality Standards have been revised to apply a dissolved metals basis and these new metals criteria are essentially equal to the existing SSWQC values for the Point Woronzof area. Since the issuance of the current NPDES permit, EPA has approved ADEC's proposed use of dissolved metals for the State's marine water quality criteria, with the exception of mercury and selenium which are under review. All of the dissolved metals acute and chronic criteria are the same as those listed in the SSWQC, except for cadmium (dissolved standard - 9.3 ug/L changed to 8.8 µg/L).

In January 2005, AWWU applied to the EPA for renewal of the discharge permit (CH2M HILL, 2004). During the preparation of these permit renewal documents, AWWU worked closely with EPA and ADEC staff to address all potential environmental concerns. In the development of the permit renewal applications, a comprehensive review of the physical environment, water quality, biological community and habitat, and protected beneficial uses of the water body in the affected region was completed. No impacts have been measured from the existing discharge, as documented in extensive monitoring since 1986 and the analyses developed for the permit applications. The results of the extensive effluent and receiving water sampling are reviewed in the following sections. The results of the monitoring and special biological studies, as they may pertain to the beluga whale health and habitat, are summarized below. The information reviewed and developed clearly indicates that the AWWU discharge at Point Woronzof poses no detrimental effects to the biological habitat in Cook Inlet or the beluga whales.

## Monitoring Program

As required by its NPDES permit, the Municipality of Anchorage has conducted extensive monitoring in the Knik Arm of Cook Inlet since 1986. In addition to monitoring processes within the treatment plant, the monitoring program includes receiving water quality monitoring and biological and sediment monitoring.

The monitoring program as described by NPDES Permit No. AK-002255-1 includes plant influent/effluent sampling; sewage sludge management procedures; water quality monitoring; biological and toxicological monitoring; and a toxics control program. The objectives of the NPDES monitoring program are to:

- determine compliance with the NPDES permit
- determine compliance with Alaska State Water Quality Standards
- determine effectiveness of the industrial pretreatment program
- assess the water quality at the discharge point
- characterize toxic substances in the Asplund WPCF effluent
- monitor the Asplund WPCF performance
- determine compliance with Section 301(h) of the Clean Water Act (CWA)
- determine the level of bacterial concentrations in nearshore waters
- monitor for changes in sediment quality near Point Woronzof
- evaluate if discharge constituents could accumulate in exposed biological organisms
- provide data for evaluations during permit renewal and reissuance

The elements of the monitoring program for the Asplund WPCF include:

1) Influent, Effluent, and Sludge Monitoring
    - In-Plant Sampling
    - Toxic Pollutants and Pesticides (including Metals and Cyanide)

- Pretreatment Monitoring
- Whole Effluent Toxicity (WET) Testing

2) Receiving Water Quality Monitoring
   - Ambient Water Quality Sampling and Field Measurements
   - Plume Dispersion Measurements
   - Intertidal Bacteria Sampling

3) Sediment and Biological Monitoring
   - Sediment and Benthic Biota Sampling and Testing
   - Bioaccumulation Studies

The monitoring program is administered by AWWU. The sampling and analyses are conducted by Kinnetic Laboratories, ToxScan, Northern Testing Laboratories, and the AWWU laboratory. State-of-the-art equipment and laboratory sampling and analysis methods are used to ensure the best possible detection. (For example, metals are analyzed by methods developed by Batelle Northwest that achieve levels of detection much lower than those required by EPA). Annual monitoring program reports are produced by AWWU and submitted to EPA in accordance with the permit requirements (Kinnetics Laboratories, 1987a, 1987b, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, and 2005).

# Effluent Quality

Effluent quality data for the Asplund WPCF have been summarized in a series of 20-year trendline plots. These graphical summaries of the effluent characteristics have been developed to illustrate the consistent performance of the facility and to highlight specific treatment improvements over the time period.

The Asplund WPCF is designed for an average flow of 58 mgd and a maximum hourly flow of 154 mgd, and the annual average daily discharge is approximately 28 mgd. The existing treatment process achieves high removal rates, in particular rates that are much higher than typical primary treatment facilities, and higher than typical advanced (chemical) primary treatment.

## TSS, BOD, Ammonia, and Oil & Grease

Over the past 20 years of operation, the Asplund WPCF effluent has shown only moderate changes to the convential pollutant discharge concentrations. Effluent total suspended solids (TSS) concentrations have gradually declined and stabilized at approximately 50 mg/L as an annual average (Figure 4). The monthly average TSS limit is 170 mg/L in the permit.

Effluent biochemical oxygen demand ($BOD_5$) have been relatively stable from 1986 through 1999, and then gradually increased during 2000 to 2003 for a variety of reasons such as increased influent BOD from seafood processing industries (Figure 5). Effluent $BOD_5$ is averaging less than 150 mg/L in recent years, compared with the monthly average limit of 240 mg/L in the permit.

Effluent ammonia, settleable solids, and oil & grease concentrations are shown in Figure 6 for the 20 year period. Routine monitoring of settleable solids ended in 1998, since values were very low and stable. Effluent ammonia measurements were initiated in 2000, and these monitoring data show stable and low concentrations (~20 mg/L) that do not pose any potential risk of ammonia toxicity. The Asplund WPCF does not have effluent ammonia limits or oil & grease limits, because of the effluent quality. Oil & grease samplings are semi-annual and consistently below 25 mg/L under the current permit.

## Dissolved Oxygen, pH, and Temperature

Over the past 20 years of operation, the Asplund WPCF effluent has shown minor changes in effluent pH, dissolved oxygen, and temperature. Effluent pH is limited to a range of 6.5 to 8.5, and over 20 years the effluent has remained within this range with only brief excursions due to weather-induced conditions (Figure 7). Effluent dissolved oxygen concentrations have trended from 4 mg/L to 7 mg/L, depending on influent BOD loads and effluent BOD (Figure 8). Effluent temperature values are influenced by ambient air temperatures and the annual average temperatures have ranged from 11 to 14 degrees C (Figure 9).

## Bacteria and Total Residual Chlorine

Figure 10 illustrates the effluent fecal coliform bacteria measurements over the last 20 years of operation. The NPDES permit limit for fecal coliform bacteria is a geometric mean of 850 colonies per 100 ml, based on at least 5 samples. This plot shows that with few individual sample excursions in 2003 and 2004, the discharge has continuously met the permit limitations for effluent fecal coliform bacteria.

The Asplund WPCF operates a chlorine feed control system to provide a flow-weighted dosing of chlorine for bacterial disinfection. In 2001, the facility implemented a project to install rapid mixing chlorine gas injection equipment. The improved effluent disinfection system allows the chlorine dosage rate to adjust based on effluent flow and oxygen reduction potential. This new disinfection control system has resulted in adequate coliform destruction along with a substantial reduction in the effluent total residual chlorine (TRC) concentrations (Figure 11). During the last four years with the new disinfection control system effluent TRC levels have averaged 0.4 mg/L or less, far below the permit limit of 1.2 mg/L.

## Effluent Metals and Organics

Over the past 20 years of operation, the Asplund WPCF effluent metals concentrations have remained stable or have declined. Figure 12 illustrates the effluent total metals concentrations of arsenic, beryllium, cadmium, chromium, copper and cyanide. Cadmium, chromium, and cyanide values have declined substantially over the record period. In direct comparison to the chronic chemical criteria for protection of aquatic organisms in the Alaska State Water Quality Standards (18 AAC 70.020(b)(23) Table IV), annual average effluent concentrations of arsenic, beryllium, cadmium, and chromium were all below the chronic receiving water criteria. Cyanide was below the chronic criteria in the 2005 data. Only copper requires some dilution within the defined Zone of Initial Dilution (ZID) to meet the criteria.

Figure 13 illustrates annual average effluent total metals concentrations of lead, mercury, nickel, silver, and zinc for the past 20 years. Mercury, nickel, and silver concentrations have declined substantially over the record period. In comparison to the chronic chemical criteria for protection of aquatic organisms in the Alaska State Water Quality Standards, recent annual average effluent concentrations of lead, nickel, and silver were at or below the chronic receiving water criteria. Other metals require some dilution within the defined Zone of Initial Dilution (ZID) to meet the criteria. These low effluent metals concentrations are an example of the effluent quality from the Asplund WPCF.

Annual average effluent total aromatic hydrocarbons (measured as total of benzene, ethylbenzene, toluene, and xylene, or BETX) are shown in Figure 14. The annual average total aromatic hydrocarbon concentrations have generally declined over the past 20 years, and these total values (prior to dilution) are nearly equal to the Alaska Water Quality Standard of 10 ug/L.

Semi-annual effluent priority pollutant analyses are performed on the Asplund WPCF effluent and these results show effluent levels are comparable to most secondary treatment facilities.

## Effluent Bioassays

As part of their NPDES permit requirements, the Asplund WPCF performs quarterly whole effluent toxicity (WET) bioassays based on 24-hr composite effluent samples. Effluent is sampled by discrete flow-proportional samplers at a well-mixed point downstream from the chlorination input point in the final effluent line.

Beginning in 2000, initial WET testing was performed as a screening period over the course of three quarters during each of which three toxicity tests were performed, each with one vertebrate and two invertebrate species. Screening included the vertebrate *Atherinops affinis* (topsmelt) for survival and growth; an invertebrate bivalve species (either *Mytilus* spp. [mussel; survival and growth] or *Crassostrea gigas* [oyster; larval development]; and an invertebrate echinoderm species fertilization test (*Strongylocentrotus purpuratus* [purple urchin] or *Dendraster excentricus* [sand dollar]). After the screening period was completed, the single most sensitive species (bivalve) was used for subsequent toxicity testing until re-screening was completed. As required by the permit, re-screening must be performed each year during one quarter (different than the previous year) to determine the most sensitive species to use for continued testing. Re-screening was performed in the second quarter of 2002 and the third quarter of 2003, with bivalves found to be the most sensitive species. Re-screening that was performed during the fourth quarter of 2004 and the third quarter of 2005 found the purple sea urchin to be the most sensitive species.

Toxicity testing is performed as required by the permit. Quality assurance for the toxicity testing includes the testing of a series of five dilutions and a control, including the concentration of the effluent at the edge of the ZID (0.70 %) as well as two dilutions above and two dilutions below 0.70 %. Reference toxicants are tested concurrently with the effluent testing, using the same procedures. If the results of a WET test shows chronic toxicity that is greater than 143 TUc (chronic toxicity units), then re-sampling and re-testing is required.

Table 1 summarizes the quarterly chronic bioassay test results under the current NPDES for the Asplund WPCF. Of a total of 60 chronic bioassay tests performed in the past six years, only two bioassay results have exceeded the chronic toxicity trigger of 143 TUc, and these occurred during the second and third quarters of 2005. As required by the permit, these exceedances triggered the treatment plant investigation of cause and retesting. Effluent toxicity results from the retesting met permit requirements for both the second and third quarters, and no additional testing was necessary. It is very important to recognize that the WET testing is designed to provide a conservative method of evaluating if there is any potential for whole effluent to cause toxicity. The use of a highly sensitive surrogate test species, such as the sea urchin fertilization test (not a species found in Cook Inlet), is a very conservative test and not representative of resident species.

# Physical Environment & Discharge

Of the many unique characteristics of Knik Arm, perhaps the most unusual are its tidal characteristics. The semidiurnal mixed tides in Knik Arm have a diurnal range of 30 feet and an extreme range of 39 feet. The tides produce swift currents and vigorous mixing off of Point Woronzof. Knik Arm exhibits high tidal velocities (up to approximately 8.2 ft/sec), extensive intertidal mudflats (60 percent of Knik Arm), a brackish salinity range (from 4 parts per thousand [ppt] in summer to 21 ppt in winter), and ice flows from November through April.

Tidally driven alternating high current velocities, interspersed by brief periods (15 to 20 minutes) of low-speed slack, have been recorded in Knik Arm. Currents are influenced primarily by the tides, freshwater inflow, and geographic features. Figures 15 and 16 illustrate the generalized current patterns in lower Knik Arm and in the vicinity of Point Woronzof during ebb and flood tides, respectively. These general patterns have been developed based on years of field measurements of current transport in this region by AWWU and others. For example, during annual receiving water monitoring for the Asplund WPCF, drogues are released into the discharge plume at the outfall and followed for sequential sampling in the water column. Figures 17 and 18 provide track-line plots of the ebb and flood tide drogue transport patterns during sampling by AWWU.

The major rivers and streams contributing fresh water to Knik Arm include the Matanuska River, Knik River, Eagle River, Ship Creek, and Chester Creek. These sources of fresh water, combined with other rivers flowing into Cook Inlet, keep the salinity of Knik Arm generally below 20 ppt. Strong tidal mixing results in weak vertical density gradients year-round.

Ambient currents in the vicinity of the Point Woronzof outfall diffuser vary in speed from 8 cm/sec to a maximum to 250cm/sec. The lowest 10$^{th}$ percentile, the 50$^{th}$ percentile, and the 90$^{th}$ percentile current speeds are 46 cm/sec, 136 cm/sec, and 195 cm/sec, respectively.

Flushing time in Knik Arm, the time required for the volume of water in Knik Arm to be replaced, is a function of advective flow (riverine input) and tidal excursion (net distance a particle moves each tidal cycle). Calculations of tidal excursion suggest a net excursion exists in the ebb direction of approximately 3 miles, after a flood excursion of 19 to 20 miles and an ebb excursion of 22.5 to 23.2 miles. These high excursions contribute to the rapid flushing rates for Knik Arm. In general, field studies demonstrate large tidal excursions and currents that provide an overall rapid flushing rate (on the order of days) that is greater in spring and summer (times of high freshwater inflow) than in winter.

These physical characteristics result in conditions that are very advantageous for the Asplund WPCF treated wastewater discharge. Figure 19 shows "snapshots" of the effluent plume transport from the Point Woronzof outfall discharge over a 24-hour time-series. This time-series clearly illustrates the small spatial dimensions of the detectable discharge plume relative to the width of Knik Arm. The discharge plume is less than 1 percent of the cross-sectional width of Knik Arm at its narrowest constriction point. Under normal ebb or flood tidal currents, plume dilutions exceed 1,000:1 within 1,000 meters of the discharge, and under initial tidal reversals dilutions would still exceed 400:1 within 1,000 meters of the discharge (CH2M HILL, 2004). Under the extreme tidal ranges and highest current speeds at the discharge site a *short-lived* minimum dilution of 180:1 is predicted by modeling of the discharge (not including any turbulent mixing). The high current speeds and turbulent mixing also prevent any accumulation of wastewater solids in the bottom sediments, and the flushing rate prevents any build-up over time of pollutants in Knik Arm.

# Water Quality

## Water Column Measurements & Samples

Riverine discharges to Knik Arm at the upper end of Cook Inlet carry high total suspended solids (TSS) loads that originate from the natural processes of glacial scour of underlying rock in the watershed. Theses high TSS loads are kept in suspension by Knik Arm's rapid currents. The suspended solids concentration in Cook Inlet varies from 240 to 2,480 mg/L. The maximum monthly average effluent suspended solids concentration limit in the Asplund WPCF NPDES permit is 170 mg/L. In applying this TSS limit, suspended solids concentration at the completion of initial dilution could vary from 239 mg/L to 2,464 mg/L. The actual effluent TSS concentrations in 2005 ranged from 54 mg/L (annual average) to 58 mg/L (maximum month). Effluent discharge into Cook Inlet reduces the suspended solids concentration of the receiving water and will slightly decrease receiving water turbidity. Receiving water monitoring has also shown no impact of the discharge on turbidity.

Table 2 provides a summary of receiving water temperature, salinity, dissolved oxygen, and turbidity measurements collected each spring or summer period over the last ten years at the Point Woronzof outfall (in plume), nearfield (in ZID and plume), and at the Point MacKenzie control station across Knik Arm. These measurements were collected at the plume depth in the water column for each sampling date.

Variations in salinity result from changes in the freshwater inflow and tidal influence. The NPDES monitoring data show some seasonal and spatial variations between the control and outfall sites. Measured salinities range from 1.3 ppt at the control site in 1997 to 17.5 ppt near the outfall in 2005. This range is largely because of fresh water runoff in the summer throughout the inlet.

Available monitoring data indicate that dissolved oxygen in Knik Arm is near saturation with little vertical stratification, and measured concentrations range from 6.1 to 13.6 mg/L. The calculated maximum dissolved oxygen depression caused by the wastewater discharge was calculated to be 0.06 mg/L, which is not measurable in the field. The rapid currents and turbulent mixing at the discharge site prevent any depletion of dissolved oxygen. In all seasons, the ambient dissolved oxygen exceeds Alaska's water quality standard of 5 mg/L. DO values within the ZID and at the ZID boundary stations were well within the seasonal range of the control station values.

Nitrogen, phosphorus, and silica are typically found in very low concentrations. Concentrations of these nutrients measured by Murphy, et al. (1972) and Kinnetic Laboratories (1979) in Knik Arm are provided in Tables 3 and 4, respectively. All three nutrients were found in concentrations lower than those typical for seawater.

From 1986 to the present, the NPDES monitoring program has included sample collections at intertidal (shoreline) stations and at offshore stations for fecal coliform analyses. The intertidal (shoreline) sampling program includes sampling stations near the mouths of the three main creeks that discharge near this intertidal region (refer to Figure 2). These three creeks have consistently shown elevated bacteria concentrations that influence the intertidal shoreline areas of Anchorage. The intertidal stations monitoring data show fecal coliform concentrations range from 2 to 80 FC/100 mL at the eight stations near Point Woronzof (IT0 through IT7), and range from 2 to 13 FC/100 mL at the station located across Knik Arm, near Point Mackenzie (IT-C). These data show that the highest fecal coliform concentrations are consistently found in the waters of the three creeks, with values ranging from 2 to 5,900 FC/100 mL.

The offshore sampling program includes sampling stations within the ZID, at the ZID boundary, at nearfield stations, and at control stations located across Knik Arm, near Point Mackenzie. Table 5 summarizes the fecal coliform concentrations in samples collected during the offshore monitoring over the last 10 years. The fecal coliform concentrations (geometric mean) range from 2 to 83 FC/100 mL at the station within the ZID boundary, 2 to 42 FC/100 mL at the nearfield stations, 2 to 100 FC/100 mL at the creeks, and 2 to 13.5 FC/100 mL at the control station across Knik Arm. With the background influence of the discharges from Fish, Ship, and Chester Creeks into the shoreline water at Point Woronzonf, there is uncertainty in discerning patterns to the bacteria levels in the offshore waters. Figure 20 illustrates the offshore sampling results for the past ten years of monitoring, and the creeks are clearly the primary source of bacteria.

Alaska's most restrictive criterion for receiving water fecal coliform bacteria concentrations is in shellfish harvest areas, which specifies that the median value shall not exceed 14 MPN/ 100 m/L, and that not more than 10 percent of the samples shall exceed 43 MPN/100 m/L. Because Cook Inlet is protected for this use, the discharge must result in this standard being met at the edge of the zone of initial dilution. Due to the large amount of dilution available, the criterion is met, and no impact to shellfish occurs.

The NPDES monitoring program has included surface water sample collections and analysis for metals since 1986, although this is not a requirement of the NPDES permit. Surface water samples are collected within the ZID, at the ZID boundary, at a nearfield station, and at three control stations. The receiving water samples collected at the control stations have been used to represent the background metals concentration in Knik Arm.

The background total recoverable metals concentrations in the Knik Arm are elevated by the suspended solids concentrations in the water column (TSS values at discharge site range between 150 and 2,400 mg/L). The total recoverable metals concentrations of copper, nickel, and zinc are nearly always above the Alaska total recoverable criteria, and arsenic, chromium, lead, and mercury periodically exceed the criteria. However, these are not the bioavailable metal concentrations, which are represented by the dissolved metals concentrations.

The Point Woronzof discharge contains very low concentrations of toxic pollutants. Calculations estimating the effect of the Point Woronzof discharge on water quality in Knik Arm show that the discharge does not cause any exceedance of water quality criteria for metals and organics. Knik Arm does, however, contain naturally high levels of particulate metals. The available evidence demonstrates that these metals are associated with glacial scour sediments from riverine input. Analyses performed indicate clearly that the non-dissolved fraction of metals, and the ambient levels of turbidity in Knik Arm are highly correlated with TSS load from the riverine inputs, *bound in mineral particles in the TSS load, and are not bioavailable*.

Field measurements have been analyzed in various ways, including hydrodynamic and transport modeling, to assess the relative contribution to background from the effluent and naturally derived watershed sources. The estimated effluent contribution from the Point Woronzof discharge was estimated to be on the order of 0.01 to 1 percent of the background concentrations. *The effect of the discharge is negligible.* Analyses performed show that the riverine loadings can easily account for most of the dissolved and virtually all of the total recoverable metals in the receiving water. There is little doubt that the riverine loadings of total recoverable metals are the primary source of these substances.

# Biological Conditions

## Plankton

Phytoplankton and zooplankton abundance in Knik Arm is very low. Low light penetration (less than 10 cm) associated with the high TSS limits phytoplankton growth. Rapid currents prevent any long-term exposure of plankton to the Point Woronzof discharge and thus minimize the effect of any toxicity. In addition, no nuisance plankton blooms have ever been reported in Knik Arm.

## Sediment and Benthic Invertebrates

Benthic invertebrate abundance in Point Woronzof is naturally very low. The subtidal sediment in this area comprises rounded gravel and boulders with only traces of silt and sand. Surveys by divers and using surface sampling devices have produced almost no subtidal organisms. The rapid currents and ice scour during the winter maintain a biologically barren subtidal benthic environment.

Intertidal benthic organisms are more abundant but still relatively sparse. Their patchy distribution, low diversity, and low biomass are the result of physical stresses caused by low and fluctuating salinity, extreme intertidal temperature fluctuation, and mechanical disturbance of the substrate resulting from the wide tide range, strong currents, and winter ice.

As required by the permit, intertidal and subtidal sediment sampling was conducted in 1989 and 2003. Results of these sampling events are briefly discussed below.

### 1989 Intertidal and Subtidal Sediment Sampling

Three intertidal sediments were collected in 1989 and analyzed for metals, pesticides & organic priority pollutants. Two were collected southeast of Point Woronzof in the vicinity of the outfall while the third was collected at the control site northeast of Point Mackenzie in Knik Arm. Two replicates were collected at each station. The range of metals was consistent between the outfall stations and control station and no pesticides or priority pollutants were detected (Kinnetics Laboratories, 1989).

Two subtidal sediments were collected as well during 1989. One was collected near the outfall and one near the control station. Two replicates were collected at each station. The substrate encountered during dredging consisted mainly of large cobbles and lesser amounts of coarse gravel. As no fine grained sediments were encountered chemical analyses could not be performed (Kinnetics Laboratories, 1989).

### 2003 Intertidal and Subtidal Sediment Sampling

Sediment samples were collected for chemistry analyses from three intertidal stations in 2003. Three replicates were collected at each station. As in 1989, two were collected from the vicinity of the outfall while the third was collected from the control station near Point Mackenzie. Chemical analysis included total volatile solids (TVS), and toxic pollutants, including metals and pesticides. No semi-volatile compounds, pesticides, dioxins, or asbestos were found in any of the samples that were analyzed. A number of volatile compounds at low concentrations were found in one replicate from the outfall side. These compounds included ethylbenzene, toluene, and xylenes that are normally associated with gasoline and some other petroleum products and methylene chloride which is a common laboratory solvent and contaminant, and these were not be attributed to the outfall.

Other analyses that were performed included 13 priority pollutant metals and cyanide. Cyanide was detected near the detection limit in the one replicate from the control station. Concentrations of metals were very similar between stations and were very typical for marine sediment concentrations with no sign of elevated concentrations. A few of the metals appeared to be slightly lower at the control site versus the two locations nearer to the outfall, which were attributed to the lower TVS and associated total organic carbon content (Kinnetics Laboratories, 2004). As in 1989, all subtidal sample material collected in 2003 consisted of cobbles and coarse grained gravel and could not be subjected to chemical analyses.

## Fisheries

While fisheries resources are abundant and diverse in Cook Inlet as a whole, the resource and fisheries within Knik Arm are generally limited to salmonids. In upper Cook Inlet there are important fisheries for all anadromous salmonid species present, including: chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*), pink (*O. gorbuscha*), and chum (*O. keta*) salmon; steelhead trout (*O. mykiss*); and Dolly Varden char (*Salvelinus malma*).

Fisheries for Pacific herring (*Clupea pallasi*), Pacific halibut (*Hippoglossus stenolepis*), King crab (*Paralithodes camtschatica*), Tanner crab (*Chionoectes bairdi*), Dungeness crab ( *Cancer magister*), various ground fish, and razor clams (*Silica patula*) are not conducted in the Knik Arm and Anchorage vicinity, mostly because they are not present or not present in sufficient quantity to support a fishery. The primary reason for this is the glacial and estuarine nature of the area. The low salinity and high degree of turbidity due to glacial influence preclude many marine species from using this area extensively. The high degree of turbidity severely limits the amount of photosynthesis that can occur and hence biological productivity in general.

Knik Arm is, however, an important migratory pathway for anadromous species using the many streams and rivers of the area. The major salmon-producing waters in the Anchorage vicinity are, in order of importance, The Susitna, Little Susitna, and Matanuska Rivers and Bird, Ship, and Campbell Creeks. The Susitna River, by far the most important salmon-producing river in the vicinity, is functionally outside of the project area.

### Salmonids

The Anchorage area has all of the species of salmonids listed for Cook Inlet present at various times of the year. Adult salmon arrive from late spring to early fall from open ocean areas where they reared for 1 to 7 years, depending upon species, genetic disposition, and environmental conditions. All spawn in freshwater systems, rear for variable periods, and emigrate back out to estuarine and ocean rearing areas in spring.

The abundance and importance of salmonids in the Anchorage area can be described with a number of statistics. Abundance is described with spawning numbers (escapement), and run size (escapement + harvest). Importance can be described in terms of commercial and sport fishing harvest, but also includes subsistence harvest, secondary economic contribution, and social values that are unquantifiable.

Salmon runs to the Anchorage area are dominated by those returning to the Susitna River system. Salmon runs to Knik Arm are a composite of many streams and rivers feeding the estuary without a dominant system. Despite the large relative size of the Matanuska and Knik Rivers, their salmon production is relatively modest. The production numbers for these systems are unknown as ADFG does not monitor natural production in these systems. However, salmon escapement is regularly monitored in the rivers and streams in the immediate vicinity of Anchorage (Table 6). Six-Mile Creek has the largest returns, composed primarily of sockeye. Campbell and Ship Creeks are primarily chinook- and coho-producing systems with total run sizes of 2,500 and 1,400 salmon, respectively, in recent years.

Hatchery-generated runs occur in Knik Arm as the result of four operations, two of which are owned by ADFG and two owned by the Cook Inlet Aquaculture Association (CIAA). The Eklutna operation began in the 1970s as a chum salmon enhancement facility. It was converted to sockeye culture in 1992. The Big Lake Hatchery, also a sockeye facility, was closed in 1992. The current Eklutna program calls for annual production of 1.0 million sockeye salmon smolts and 50,000 coho smolts to be released at the hatchery site and 5.0 million sockeye fry to be released in the Big Lake drainage. At this time, few fish are returning to this facility because early brood years of sockeye salmon were destroyed due to outbreaks of IHN virus. The operation was shut down in 1999, but plants to Big Lake will continue from hatchery production at the Trail Lake facility in the Kenai River system.

ADFG owns two hatchery operations in the Anchorage area for local and regional enhancement purposes. The Elmendorf Hatchery is a mixed-species operation producing coho, chinook, graying (*Thymallus arcticus*), and Arctic char (*Salvelinus alpinus*). The Fort Richardson Hatchery produces coho, chinook, and rainbow trout. The production goal for Elmendorf is 200,000 coho smolts. Production goals for Fort Richardson are 200,000 chinook and 600,000 coho smolts.

### Salmonid Smolt Production

Salmon, after rearing in freshwater for a variable period of time as juveniles, emigrate to sea in spring. They are called smolts at this time. Smolt production in Knik Arm is composed of natural production in the rivers and creeks of Knik Arm and in hatcheries at four locations. Because salmon are the most vulnerable to water quality and environmental conditions at this period of their lives, their presence and residence in the area of the outfall vicinity are important.

Natural production is poorly monitored by ADFG in most rivers and creeks because of the expense involved. Although numbers of outmigrant smolts are not available for naturally produced salmon smolts, their abundance can be assumed to be in the millions. Hatchery production is monitored closely and well documented. The 1997 releases totaled 11.7 million fish, with 8.77 million sockeye. All of the sockeye were produced at the Eklutna Hatchery. This number will decline because the Eklutna facility is being closed this year. Production from both the Elmendorf and Fort Richardson hatcheries are planted in the many lakes and streams in the Anchorage area, primarily for sport fishing enhancement purposes. Some of the rainbow trout production is planted in the Fairbanks area.

The total number of smolts passing between Point Woronzof and Point McKenzie is unknown but numbers in the millions, most of which are sockeye salmon. The usage of nearshore waters during outmigration is extensive by the smaller smolt such as those of pink salmon and chum salmon, although chinook, coho, and sockeye will also be found nearshore as well as further offshore.

### Demersal Fish

Demersal fish live on or near the bottom. Attempts made to sample this community in 1989 were unsuccessful owing to the nature of bottom conditions and current velocities at Point Woronzof. However, some generalizations can be made on the basis of bottom type and salinity. Flatfish are not likely to be present because of the cobble, rock, and gravel present around the outfall. Sculpins and snailfish are probably present in small numbers. Their abundance is likely to be limited because food resources are low in the vicinity due to high turbidity, high current velocity, and low salinity. Species found include saffron cod (*Eleginus gracilis*), ringtail snailfish (*Liparis rutteri*), starry flounder (*Platichthys stellatus*), yellowfin sole (*Pleuronectes asper*), and Pacific staghorn sculpin (*Leptocottus armatus*). Of these, saffron cod were the most commonly caught.

## Bioaccumulation

The objectives of the bioaccumulation monitoring program since the original permit was issued in October of 1985 have been to determine compliance with the NPDES permit, to determine if pollutants from the discharge are accumulating in biological organisms, and to provide data for evaluation of permit re-issuance.

In 1986, a preparatory program was initiated to determine if a field or laboratory approach should be followed. This program included a review of existing literature to determine if locally abundant intertidal macroalgae are suitable indicators of bioaccumulation, an analysis of the benthic macroinvertebrate data to determine if a suitable test species is available in adequate quantities for testing, and the design of a bioaccumulation study. As a result of these studies, *Vaucheria* spp., algae species, was selected as the test organism to analyze for accumulation of contaminants.

Bioaccumulation sampling and testing has been conducted in 1987, 1989, 1998, and 2004 by AWWU using intertidal resident algae or fish species. Algal bioaccumulation sampling was also planned for 2003 and 2004, however due to dry summers insufficient algae accumulated in the intertidal area for sampling. In 1998, bioaccumulation sampling and testing was performed using coho salmon and saffron cod. In 2004, bioaccumulation sampling and testing was performed using Pacific cod. Results of these sampling events are briefly reviewed below.

### 1987 Algae (*Vaucheria* spp.)

Ten replicate samples each were collected at two intertidal stations in 1987. One station was located on the outfall side approximately 2,000 meters southeast of Pt. Woronzof and the other was collected at the control side approximately the same distance from Pt. Mackenzie. Samples were analyzed for metals, priority pollutants, and total hydrocarbons. No priority pollutants were detected and concentrations of total hydrocarbons were found to be meaningless due to chlorophyll content. Mercury was found to higher at the station nearest the outfall however no statistically meaningful pattern of bioaccumulation was indicated by the data.

### 1989 Algae (*Vaucheria* spp.)

Intertidal algae were sampled in 1989 at the same stations as in 1987. Samples were analyzed for metals, pesticides & organic priority pollutants. The range of metals detected was similar between the stations although slightly higher values of arsenic and cadmium were detected at the outfall compared to the control. Natural variability for metals concentrations is likely as no pattern consistent with an outfall effect was apparent. Only one pesticide was detected just over detection limit at both stations and no priority pollutants were detected (Kinnetics Laboratories, 1989).

### 1998 Coho salmon (*Oncorhynchus kisutch*) and Saffron cod (*Eleginus gracilis*)

In 1998, AWWU conducted sampling and testing of Coho salmon and Saffron cod to support their requested site specific water quality criteria (SSWQC) for the Pt. Woronzof Area of Upper Cook Inlet. Fish tissue were collected from Coho salmon and Saffron cod, and analyzed for methyl mercury concentrations. The salmon used for analysis were caught commercially at Fire Island and the Saffron cod were collected using beach seines from one location in Bootleggers Cove. Results were consistent with other available data for fish tissue in Cook Inlet that were collected during the Cook Inlet Contaminant Study conducted by EPA (EPA, 2003).

The results indicate an average muscle tissue methylmercury burden in coho salmon samples of 0.045 μg/g on a wet-weight basis. The results are consistent with the findings for fish tissue in Cook Inlet recently collected during the Cook Inlet Containment Study conducted by the EPA. The EPA sampling was done near the mouth of the Cook Inlet (Seldovia, Port Graham, and Nanwalek) and at one station in upper Cook Inlet (Tyonek). Only salmon (chinook and sockeye) were sampled at the Tyonek location, and the preliminary results indicate methylmercury burdens are below the level of concern. The measured salmon and cod tissue levels from Cook Inlet compare well with the *lowest tissue levels* monitored by the FDA (Foulke, 1995) from October 1990 to October 1991 in all commercial fish—with measured MeHg tissue levels at 0.03 μg/g wet weight in ocean perch.

### 2004 Pacific cod (*Gadus macrocephalus*)

In 2004, collection of Pacific cod was approved by the Alaska Department of Fish and Game (ADF&G) for a bioaccumulation study. The study called for the collection of three to five replicate samples from each location using a beach seine, depending on fish availability. Each replicate consisted of a composite of tissue from a number of fish in order to obtain sufficient biomass for the laboratory analyses. This study was performed in October 2004.

Shallow subtidal/intertidal bioaccumulation analyses of Pacific cod showed no evidence of outfall impacts. Data from outfall and control sites were similar in terms of chemical concentrations, with most semi-volatile compounds and pesticides, found to be at or below detection limits. Arsenic, copper, mercury, selenium, and zinc were detected in the tissues at low concentrations, but no statistically significant differences were seen between the outfall and control locations. There was no evidence that pollutants attributable to the outfall are bioaccumulating in the resident biota in Knik Arm (Kinnetics Laboratories, 2005).

### Marine Mammals in Knik Arm

The Alaska Department of Fish and Game indicate that coho salmon and saffron cod are important in the diet of seals and Beluga whales (ADF&G, 1986).

Consistent with the fish tissue levels described above, <u>studies conducted on Beluga whales in Cook Inlet have shown that the mercury concentrations in their livers are essentially the same as found in open-water Belugas</u>. A study conducted by Becker measured MeHg content of the liver of six Beluga whales (*Delphinapterus leucas*) collected from Cook Inlet (Becker, 1995). The study included liver tissue samples from two adult males, two adult females, and one female fetus. The results indicated the adult Beluga liver MeHg ranged from 0.34 to 2.11 μg/g wet weight, and the fetus had a liver concentration of 0.09 μg/g wet weight. Becker indicated that the Cook Inlet Beluga whale liver tissue compared well with samples of Beluga whale liver from Point Lay and Point Hope, Alaska, in the Chukchi Sea, where MeHg concentrations ranged between 0.37 to 2.01 μg/g wet weight. Becker also indicated that samples from all the above locations were similar to levels for Beluga whales analyzed previously from the Eastern Beaufort Sea, Arctic Canada, and Greenland.

As in the case of the other heavy metals considered, the non-dissolved fraction of mercury in the background receiving water appears to be associated with mineralized particles generated by glacial weathering of rock and introduced into the receiving water by river discharges. The non-dissolved mercury fraction is essentially unavailable for conversion to methylmercury or dissolved organic mercury, and therefore ultimately not bioavailable.

## Impact of Discharge on Biological Community

The Point Woronzof municipal discharge has not shown any impact on the area's biological community, including the marine mammal populations. The discharge has not caused warnings, restrictions, or closures: and there is no evidence that the discharge has caused any mortalities in fish or marine mammal populations.

No impact from the discharge is likely to occur because of the following combination of factors:

- A large portion of the fish community is anadromous, minimizing their length of exposure in the area. Also, the low food availability and high flushing rate limit their period of residence. Resident fish population numbers, represented by saffron cod, Bering cisco, snail fish, and longfin smelt, are also low.
- The concentration of metals in the Asplund WPCF effluent discharge is low. The concentrations meet water quality criteria necessary to protect estuarine life. Tissue analysis of saffron cod done in 1998 showed low levels of metals, equivalent to the levels found in open ocean species of fish.
- Flushing and mixing occur rapidly because of the high current speeds and tidal ranges.
- Sediments of effluent origin are minor and make up a very small proportion of those present or deposited in the estuary.

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# Tables and Figures

**Table 1**

**Quarterly Chronic Toxicity Results for the Asplund WPCF - 2000 to 2005**

| YEAR | TOXICITY SPECIES TEST | QUARTER | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| | Topsmelt (survival & growth) | NT | NT | <35.7 | <35.7 |
| 2000 | Bivalve (survival & development) | NT | NT | 71.4 | 71.4 |
| | Echinoderm (fertilization) | NT | NT | <35.7 | <35.7 |
| | Topsmelt (survival) | <35.7 | NT | NT | NT |
| | Topsmelt (growth) | <35.7 | NT | NT | NT |
| 2001 | Bivalve (survival) | <35.7 | <35.7 | <35.7 | <35.7 |
| | Bivalve (development) | <35.7 | <35.7 | 71.4 | <35.7 |
| | Echinoderm (fertilization) | 71.4 | NT | NT | NT |
| | Bivalve (survival) | ≤35.7 | <35.7 | ≤35.7 | ≤35.7 |
| | Bivalve (development) | ≤35.7 | <35.7 | 71.4 | ≤35.7 |
| 2002 | Topsmelt (survival) | NT | <35.7 | NT | NT |
| | Topsmelt (development) | NT | <35.7 | NT | NT |
| | Echinoderm (fertilization) | NT | <35.7 | NT | NT |
| | Bivalve (survival) | ≤35.7 | ≤35.7 | ≤35.7 | ≤35.7 |
| | Bivalve (development) | ≤35.7 | ≤35.7 | 71.4 | ≤35.7 |
| 2003 | Topsmelt (survival) | NT | NT | 35.7 | NT |
| | Topsmelt (growth) | NT | NT | 35.7 | NT |
| | Echinoderm (fertilization) | NT | NT | 35.7 | NT |
| | Bivalve (survival) | ≤35.7 | ≤35.7 | 71.4 | 35.7 |
| | Bivalve (development) | ≤35.7 | ≤35.7 | 71.4 | 35.7 |
| 2004 | Topsmelt (survival) | NT | NT | NT | 35.7 |
| | Topsmelt (growth) | NT | NT | NT | 35.7 |
| | Echinoderm (fertilization) | NT | NT | NT | 142.9 |
| | Bivalve (survival) | NT | NT | 71.4 | NT |
| | Bivalve (development) | NT | NT | 142.9 | NT |
| 2005 | Topsmelt (survival) | NT | NT | 35.7 | NT |
| | Topsmelt (growth) | NT | NT | 35.7 | NT |
| | Echinoderm (fertilization) | 142.9 | 286 | > 571 | 35.7 |
| | Echinoderm (fertilization) -Retest | NT | ≤ 35.7 | 142.9 | NT |

Note: Values are in chronic toxicity units (TUc)

Table 2

## Receiving Water Quality - Ten Year Data Summary

| Year | Station Grouping | Temperature Min | Temperature Mean | Temperature Max | Salinity Min | Salinity Mean | Salinity Max | Dissolved Oxygen Min | Dissolved Oxygen Mean | Dissolved Oxygen Max | Turbidity Min | Turbidity Mean | Turbidity Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | Control | 13.71 | 13.92 | 14.14 | 8.95 | 9.53 | 10.31 | 9.35 | 9.55 | 9.78 | 137 | 384 | 864 |
| | Nearfield | 13.97 | 14.28 | 14.99 | 10.21 | 11.01 | 12.19 | 9.05 | 9.40 | 9.79 | 85 | 316 | 446 |
| | Outfall | 13.99 | 14.18 | 14.35 | 10.15 | 10.90 | 11.69 | 8.51 | 9.29 | 9.57 | 78 | 338 | 484 |
| 1997 | Control | 14.28 | 15.30 | 15.84 | 1.28 | 6.12 | 8.24 | 9.31 | 9.57 | 9.91 | 70 | 269 | 640 |
| | Nearfield | 15.67 | 16.02 | 16.40 | 6.90 | 8.48 | 10.14 | 8.99 | 9.29 | 9.59 | 100 | 323 | 430 |
| | Outfall | 15.93 | 16.21 | 16.63 | 7.74 | 9.04 | 10.32 | 8.95 | 9.23 | 9.67 | 40 | 298 | 670 |
| 1998 | Control | 13.60 | 13.93 | 14.30 | 2.12 | 6.09 | 7.83 | 9.54 | 9.77 | 10.11 | 88 | 317 | 488 |
| | Nearfield | 13.59 | 14.01 | 14.23 | 4.41 | 7.36 | 9.09 | 9.41 | 9.70 | 10.11 | 98 | 347 | 465 |
| | Outfall | 13.05 | 13.97 | 14.44 | 2.93 | 6.99 | 8.73 | 9.28 | 9.72 | 10.24 | 40 | 324 | 436 |
| 1999 | Control | 12.90 | 13.56 | 14.00 | 6.00 | 7.65 | 10.32 | 8.67 | 9.12 | 9.85 | 169 | 352 | 557 |
| | Nearfield | 13.20 | 13.48 | 13.80 | 7.40 | 8.61 | 10.15 | 8.78 | 9.13 | 9.55 | 283 | 375 | 451 |
| | Outfall | 13.00 | 13.43 | 13.80 | 5.56 | 8.23 | 9.69 | 9.00 | 9.40 | 9.85 | 207 | 382 | 513 |
| 2000 | Control | 13.80 | 14.30 | 14.70 | 4.34 | 7.13 | 9.01 | 9.18 | 9.44 | 10.02 | 178 | 346 | 500 |
| | Nearfield | 13.50 | 14.13 | 14.60 | 4.39 | 7.24 | 8.42 | 9.08 | 9.43 | 9.60 | 130 | 331 | 850 |
| | Outfall | 13.90 | 14.20 | 14.80 | 2.70 | 7.43 | 8.41 | 9.14 | 9.39 | 9.62 | 150 | 329 | 580 |
| 2001 | Control | 13.96 | 14.29 | 14.88 | 4.05 | 11.72 | 13.42 | 9.02 | 9.28 | 9.55 | 27 | 166 | 391 |
| | Nearfield | 13.30 | 13.82 | 14.56 | 4.20 | 12.48 | 14.16 | 9.10 | 9.25 | 9.49 | 21 | 126 | 206 |
| | Outfall | 13.00 | 13.72 | 14.22 | 5.21 | 12.50 | 14.28 | 9.10 | 9.27 | 9.50 | 42 | 119 | 175 |
| 2002 | Control | 14.80 | 15.07 | 15.36 | 7.58 | 8.39 | 9.40 | 7.29 | 9.18 | 11.44 | 103 | 403 | 845 |
| | Nearfield | 15.22 | 15.37 | 15.74 | 8.27 | 9.77 | 12.04 | 8.13 | 9.27 | 9.73 | 71 | 297 | 511 |
| | Outfall | 15.20 | 15.40 | 16.00 | 8.20 | 9.62 | 11.25 | 8.70 | 9.40 | 11.62 | 16 | 277 | 415 |
| 2003 | Control | 13.69 | 13.82 | 14.13 | 9.70 | 11.47 | 12.82 | 8.80 | 9.39 | 10.02 | 34 | 207 | 456 |
| | Nearfield | 13.24 | 13.63 | 13.83 | 11.40 | 12.94 | 15.41 | 9.16 | 9.86 | 10.78 | 75 | 211 | 384 |
| | Outfall | 13.28 | 13.64 | 13.80 | 11.60 | 12.91 | 15.13 | 9.27 | 9.92 | 12.08 | 68 | 215 | 342 |
| 2004 | Control | 14.21 | 14.59 | 15.07 | 9.25 | 9.77 | 10.29 | 6.05 | 10.17 | 11.63 | 66 | 414 | 590 |
| | Nearfield | 13.80 | 14.33 | 14.83 | 8.85 | 9.39 | 9.80 | 10.37 | 11.73 | 13.59 | 110 | 414 | 560 |
| | Outfall | 13.81 | 14.42 | 15.03 | 8.80 | 9.45 | 10.08 | 10.35 | 11.58 | 13.45 | 130 | 433 | 510 |
| 2005 | Control | 10.60 | 10.91 | 11.48 | 12.80 | 15.19 | 16.10 | 9.97 | 10.03 | 10.07 | 229 | 420 | 539 |
| | Nearfield | 9.58 | 10.41 | 11.65 | 15.66 | 16.60 | 17.55 | 9.84 | 10.06 | 10.19 | 189 | 366 | 493 |
| | Outfall | 9.62 | 10.45 | 11.10 | 15.79 | 16.54 | 17.50 | 9.93 | 10.05 | 10.18 | 194 | 371 | 496 |
| All | Control | 10.60 | 13.97 | 15.84 | 1.28 | 9.42 | 16.10 | 6.05 | 9.55 | 11.63 | 27 | 328 | 864 |
| | Nearfield | 9.58 | 13.78 | 16.40 | 4.20 | 10.78 | 17.55 | 8.13 | 9.80 | 13.59 | 21 | 303 | 850 |
| | Outfall | 9.62 | 13.96 | 16.63 | 2.70 | 10.36 | 17.50 | 8.51 | 9.72 | 13.45 | 16 | 309 | 670 |

Note: Data includes all stations and all depths. Stations include: 12 outfall, 12 nearfield, and 12 control for each sampling event.

TABLE 3
Nutrient Concentrations in Knik Arm

| | Total Nitrogen (mg/L) | | | Total Phosphorus (mg/L) | | | Silica (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Avg. | Max. | Min. | Avg. | Max. | Min. | Avg. | Max. | Min. |
| 11/06/69 | 0.237 | 0.323 | 0.141 | 0.0022 | 0.0028 | 0.0009 | 1.27 | 1.49 | 1.04 |
| 03/05/70 | 0.191 | 0.210 | 0.113 | 0.0074 | 0.0074 | 0.0031 | 1.27 | 1.40 | 0.73 |
| 05/21/70 | 0.147 | 0.171 | 0.094 | 0.0097 | 0.014 | 0.0053 | 1.34 | 1.69 | 0.73 |
| 08/17/70 | 0.21 | 0.344 | 0.142 | 0.0066 | 0.012 | N.D. | 2.39 | 2.53 | 2.22 |

Source: Murphy, et al. (1972).

TABLE 4
Nutrient Concentration Data Collected in Knik Arm

| | Dissolved Phosphorus (mg P/L) | Dissolved Silica (mg Si/L) | $NO_{3^-}$ (mg N/L) | $NO_{2^-}$ (mg N/L) |
|---|---|---|---|---|
| High Slack Water Depth | | | | |
| Surface | 0.112 | 1.60 | 0.24 | 0.01 |
| Middle | 0.155 | 1.61 | 0.26 | 0.01 |
| Bottom | 0.096 | 1.61 | 0.19 | 0.01 |
| Low Slack Water Depth | | | | |
| Surface | 0.079 | 1.46 | 0.25 | 0.01 |
| Middle | 0.068 | 1.44 | 0.18 | 0.01 |
| Bottom | 0.093 | 1.45 | 0.35 | 0.01 |

Source: Kinnetic Laboratories, August 1979, measured 460 m off chlorination tower in 15 m of water.

**Table 5**
**Ten Year Summary of Fecal Coliform Bacteria Data for Receiving Waters**

| YEAR | STATION GROUPING | FECAL COLIFORM | |
|---|---|---|---|
| | | GEOMETRIC MEAN | MEDIAN |
| 1996 | Control | 1.8 | 2.05 |
| | Creeks | 38.3 | 32.4 |
| | Intertidal | 1.5 | 1 |
| | Nearfield | 1.36 | 1 |
| | Within Mixing Zone | 1.98 | 2 |
| 1997 | Control | 4.5 | 5.7 |
| | Creeks | 16.5 | 13.5 |
| | Intertidal | 7.1 | 9.2 |
| | Nearfield | 5.53 | 5.1 |
| | Within Mixing Zone | 8.85 | 12.6 |
| 1998 | Control | 6.8 | 7.15 |
| | Creeks | 59.2 | 30 |
| | Intertidal | 10.2 | 11.1 |
| | Nearfield | 11.72 | 16 |
| | Within Mixing Zone | 19.07 | 16 |
| 1999 | Control | 3.9 | 4.9 |
| | Creeks | 92.9 | 130 |
| | Intertidal | 6.0 | 6.1 |
| | Nearfield | 4.38 | 4.5 |
| | Within Mixing Zone | 5.00 | 6.15 |
| 2000 | Control | 9.6 | 13.5 |
| | Creeks | 100.2 | 70 |
| | Intertidal | 6.0 | 5.5 |
| | Nearfield | 4.66 | 4 |
| | Within Mixing Zone | 7.85 | 7.5 |
| 2001 | Control | 2.0 | 2 |
| | Creeks | 27.1 | 60 |
| | Intertidal | 5.5 | 3 |
| | Nearfield | 2.78 | 2 |
| | Within Mixing Zone | 2.24 | 2 |
| 2002 | Control | 2.8 | 3 |
| | Creeks | 39.4 | 90 |
| | Intertidal | 8.8 | 6 |
| | Nearfield | 2.95 | 2 |
| | Within Mixing Zone | 4.02 | 4 |
| 2003 | Control | 8.0 | 8 |
| | Creeks | 18.2 | 13 |
| | Intertidal | 9.9 | 11 |
| | Nearfield | 42.44 | 30 |
| | Within Mixing Zone | 83.24 | 80 |
| 2004 | Control | 2.8 | 3 |
| | Creeks | 2.0 | 2 |
| | Intertidal | 2.4 | 2 |
| | Nearfield | 2.00 | 2 |
| | Within Mixing Zone | 2.39 | 2 |
| 2005 | Control | 2.8 | 3 |
| | Creeks | 6.4 | 7.5 |
| | Intertidal | 2.1 | 2 |
| | Nearfield | 2.35 | 2 |
| | Within Mixing Zone | 3.03 | 2 |

**TABLE 6**
**Salmon Escapement Counts for Selected Rivers and Streams in Knik Arm, 1990 to 1997 (Averages)**

| | Chinook | Coho | Sockeye | Pink | Chum | Total |
|---|---|---|---|---|---|---|
| Campbell Creek | 777 | 1,246 | 511 | 2 | 3 | 2,539 |
| Ship Creek | 575 | 576 | 4 | 225 | 28 | 1,408 |
| Six-Mile Creek | 0 | 18 | 2,434 | 898 | 3 | 3,353 |
| Eagle River | 374 | 2 | 0 | 0 | 0 | 376 |
| Total | 1,726 | 1,842 | 2,949 | 1,125 | 34 | 7,767 |

Source: ADFG, 1998.

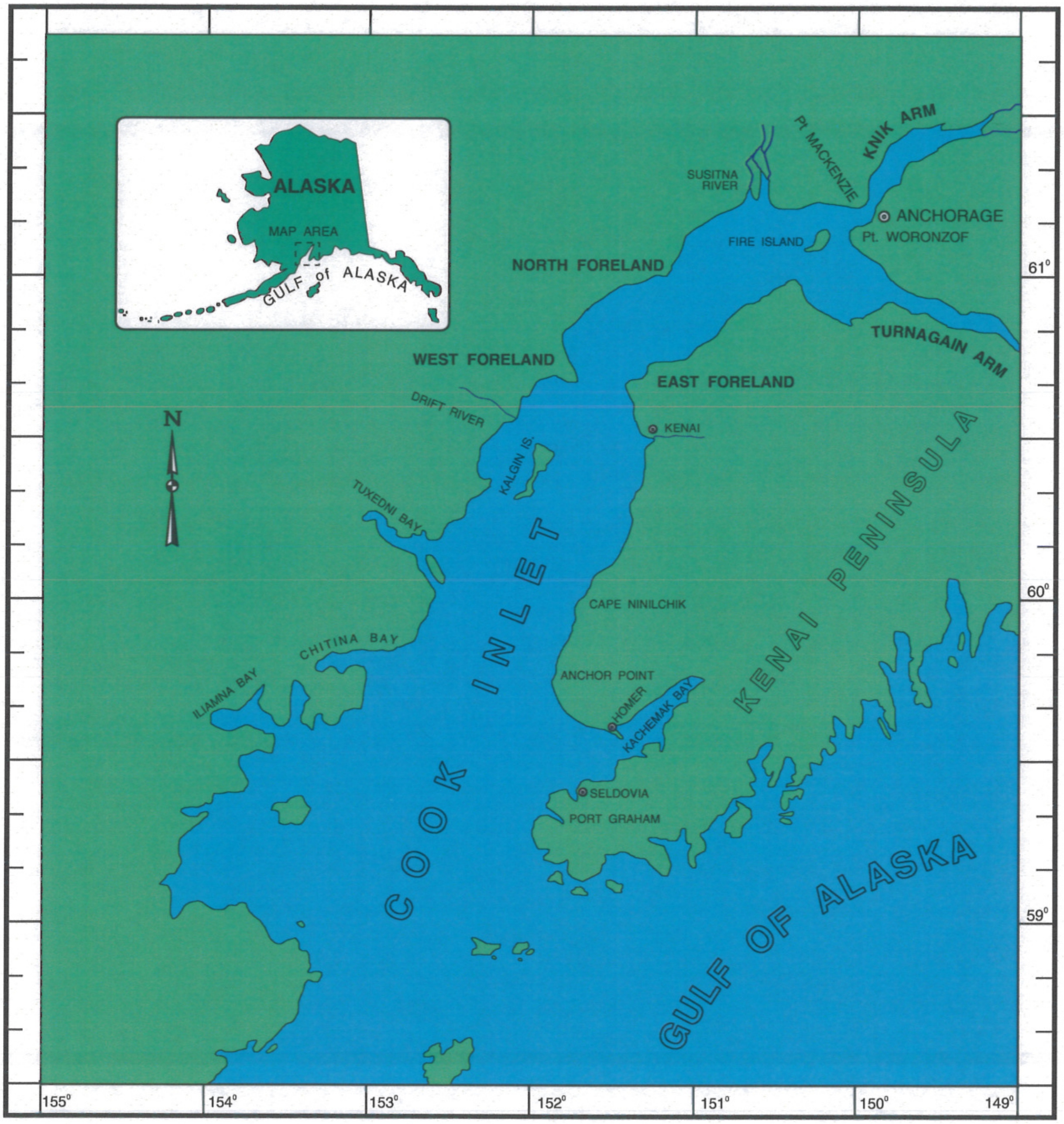



**Figure 1. General Study Area.**

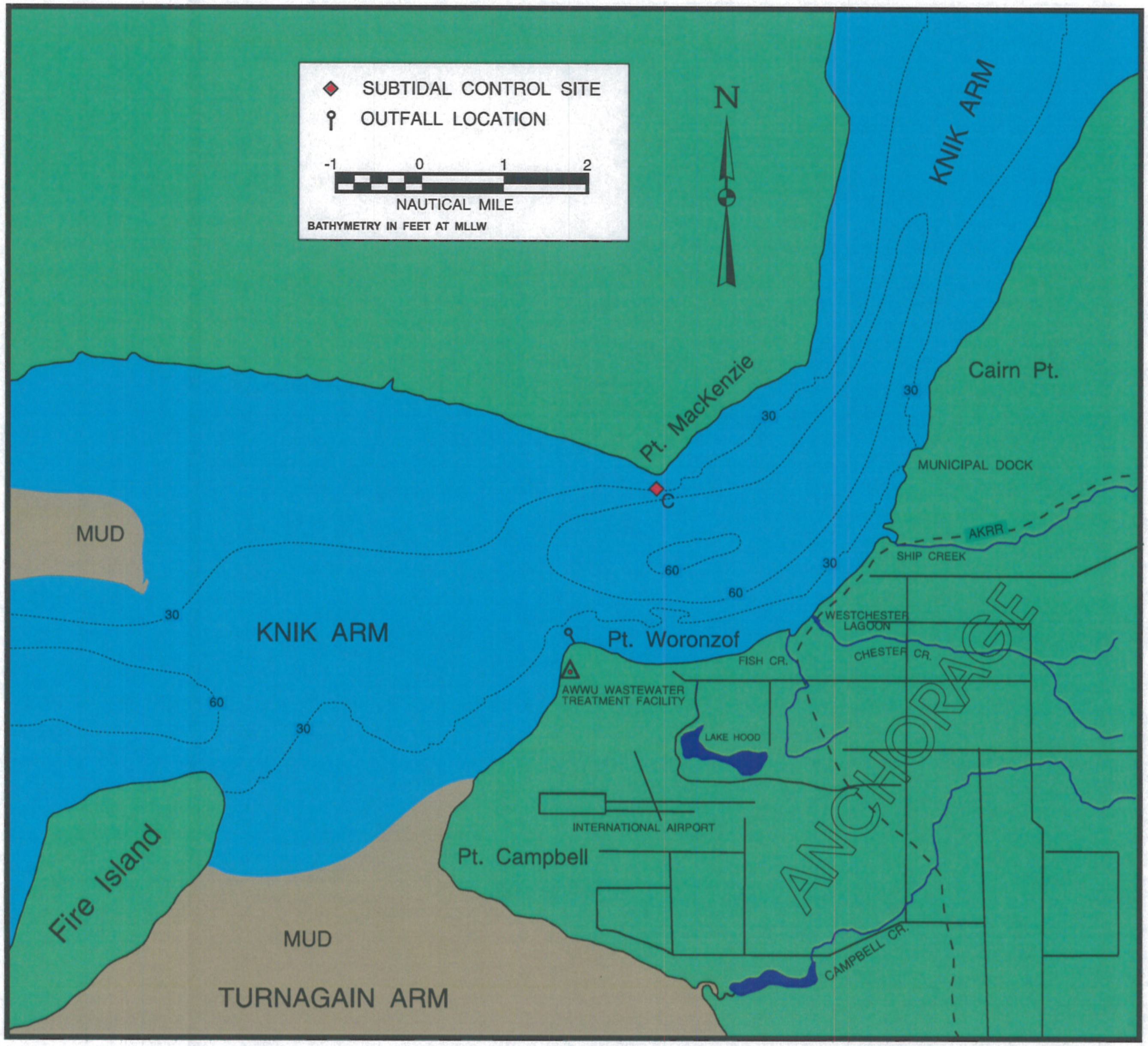



**Figure 2. Asplund WPCF Outfall and Control Station Locations.**

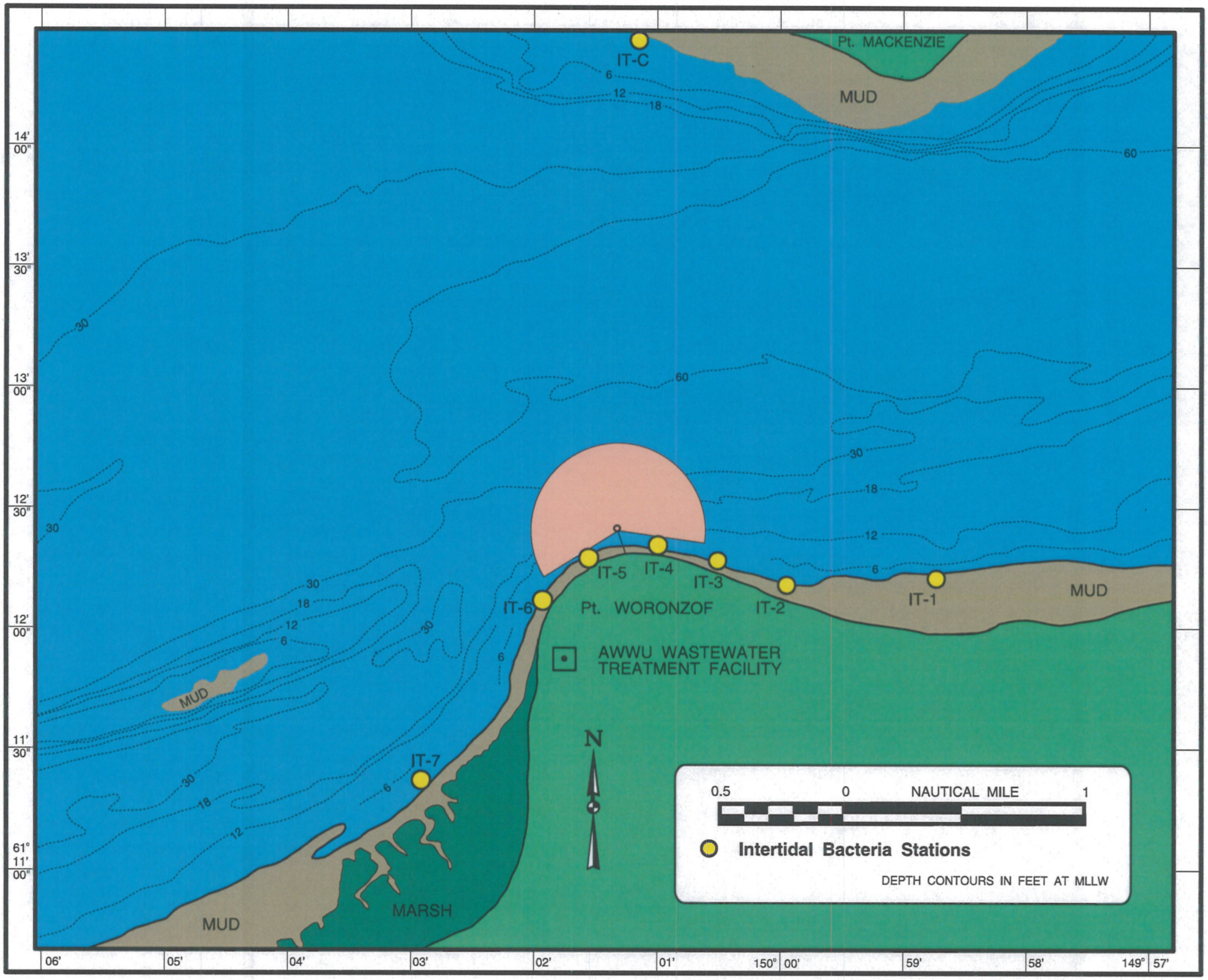



**Figure 3. Asplund WPCF Outfall, ZID, and Locations of Intertidal Bacteriological Sampling.**

**Figure 4. Annual Average and Range of Effluent Total Suspended Solids (TSS) for the Asplund WPCF - 1986 to 2005**

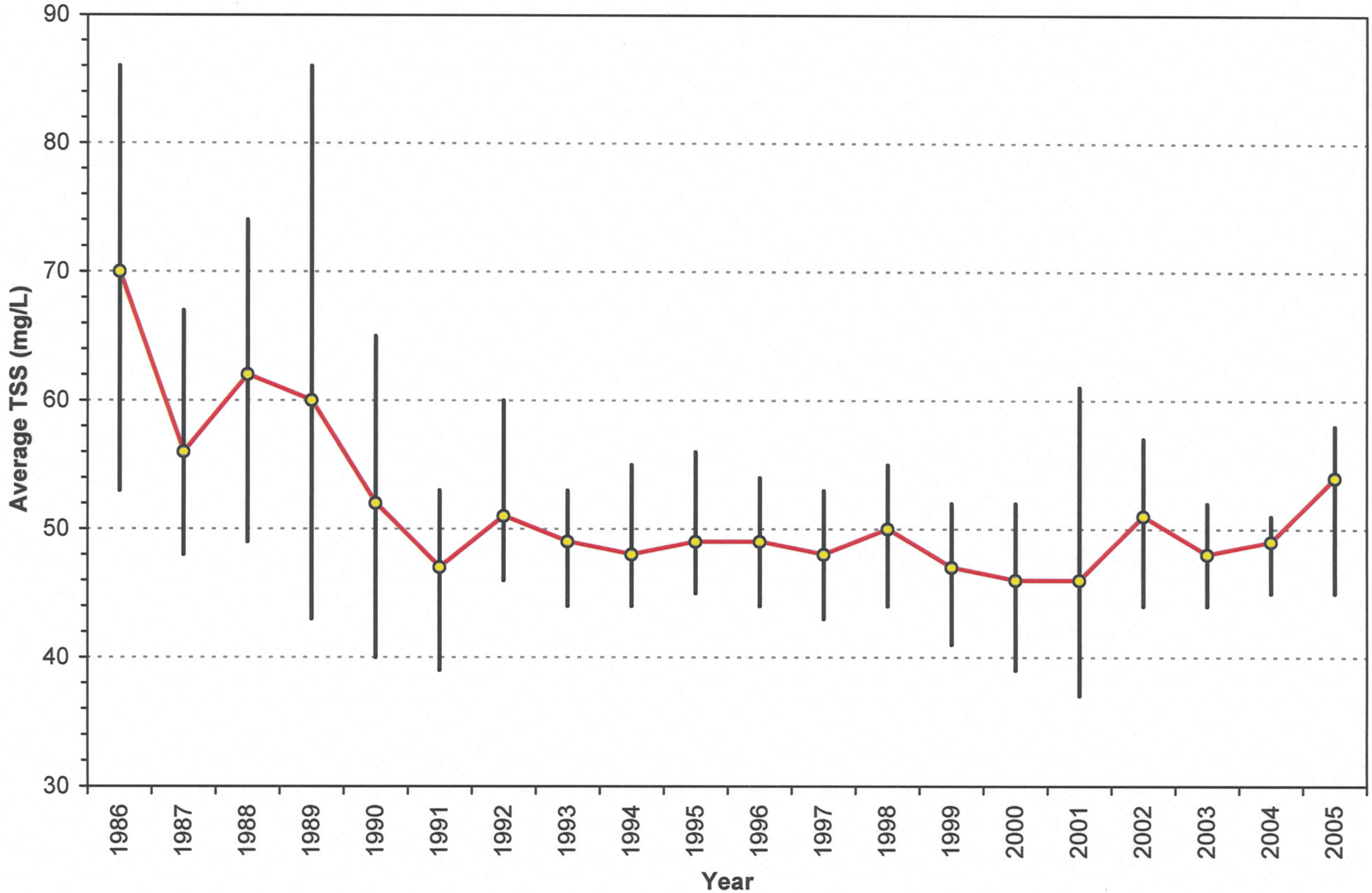


Figure 5. Annual Average and Range of Effluent $BOD_5$ for the Asplund WPCF - 1986 to 2005

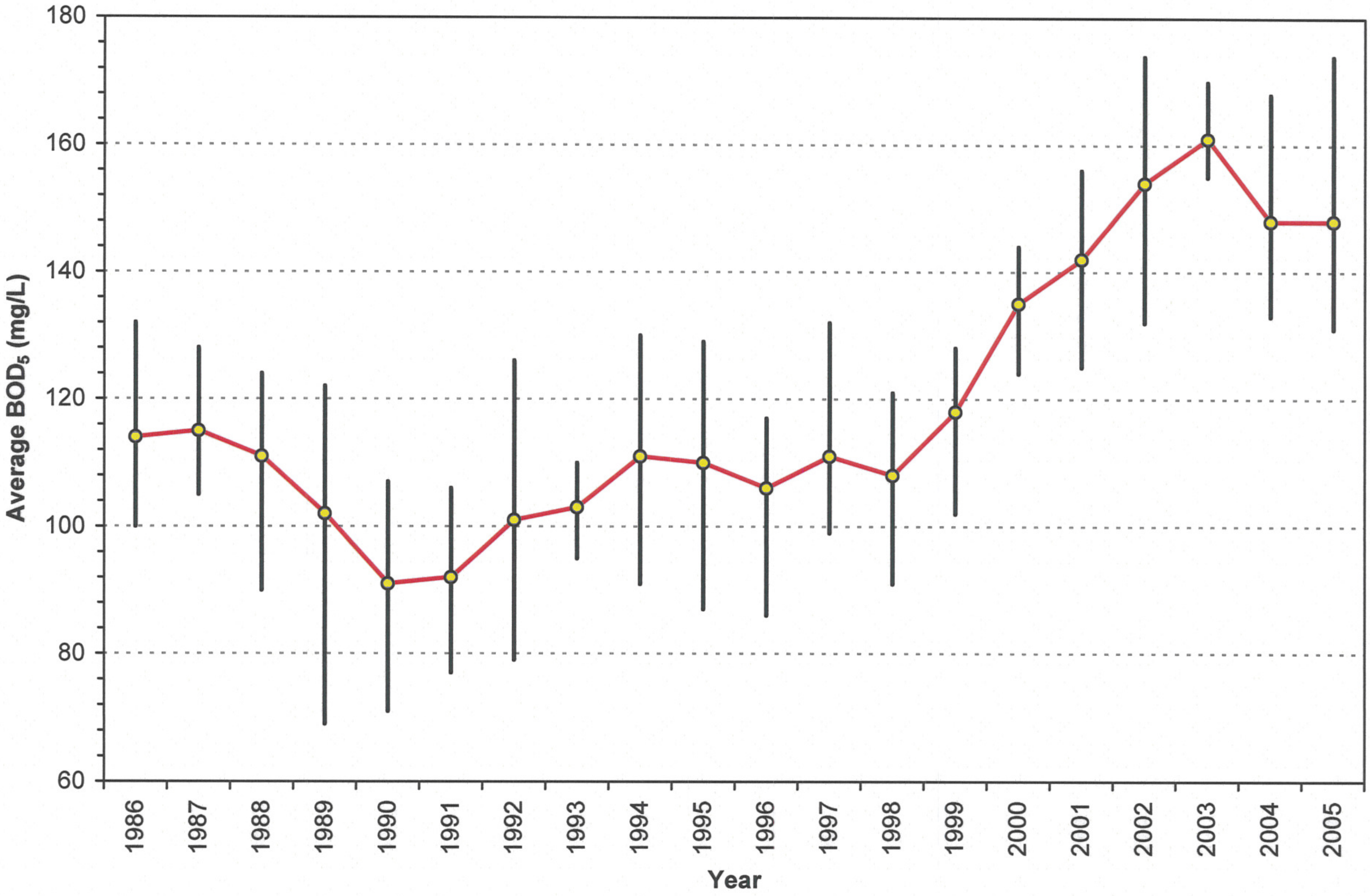


Figure 6. Plot of Annual Average Effluent Ammonia, Settleable Solids, and Oil & Grease for the Asplund WPCF - 1986 to 2005

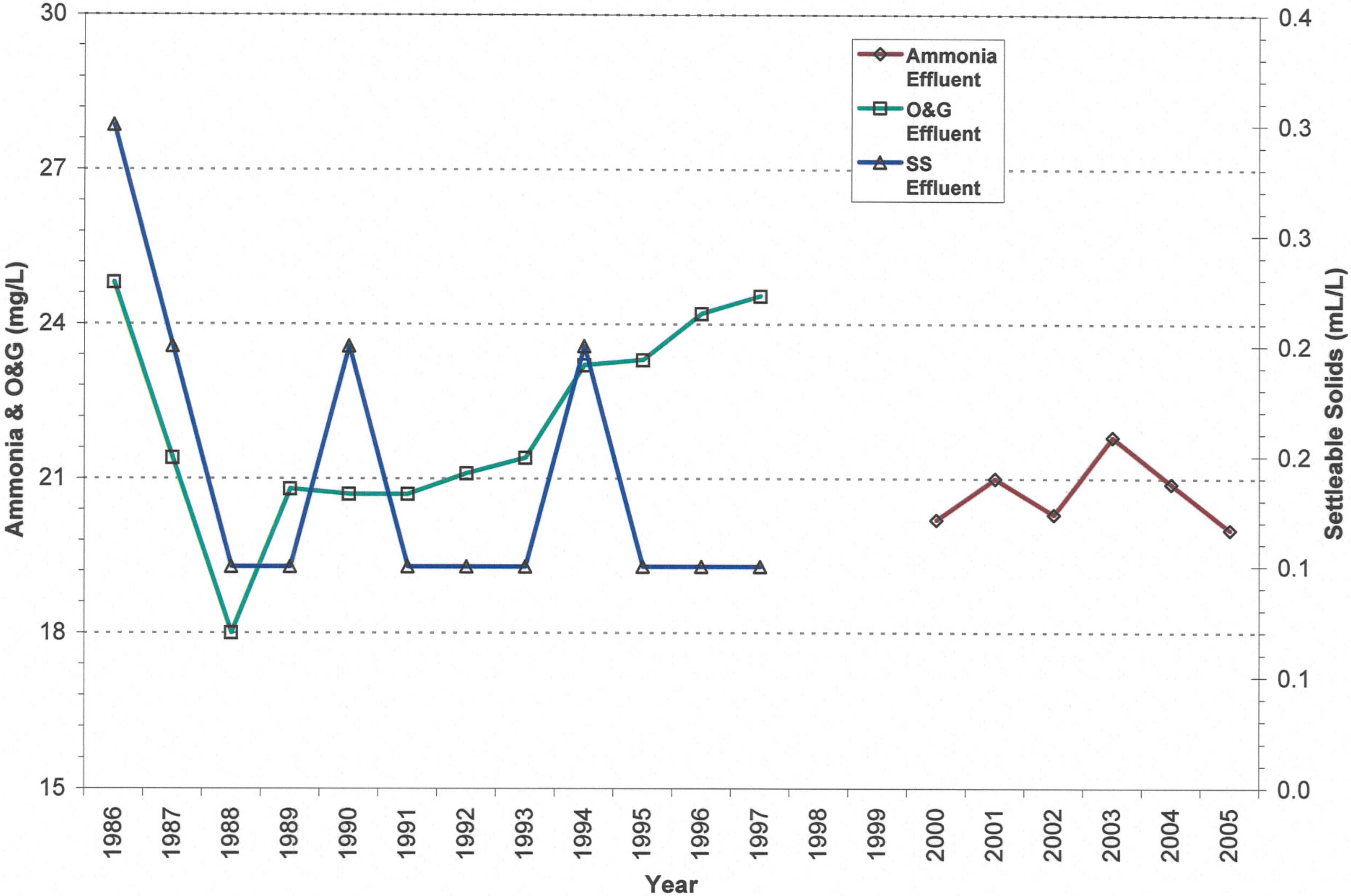


Figure 7. Annual Averages and Range of Effluent pH for the Asplund WPCF - 1986 to 2005

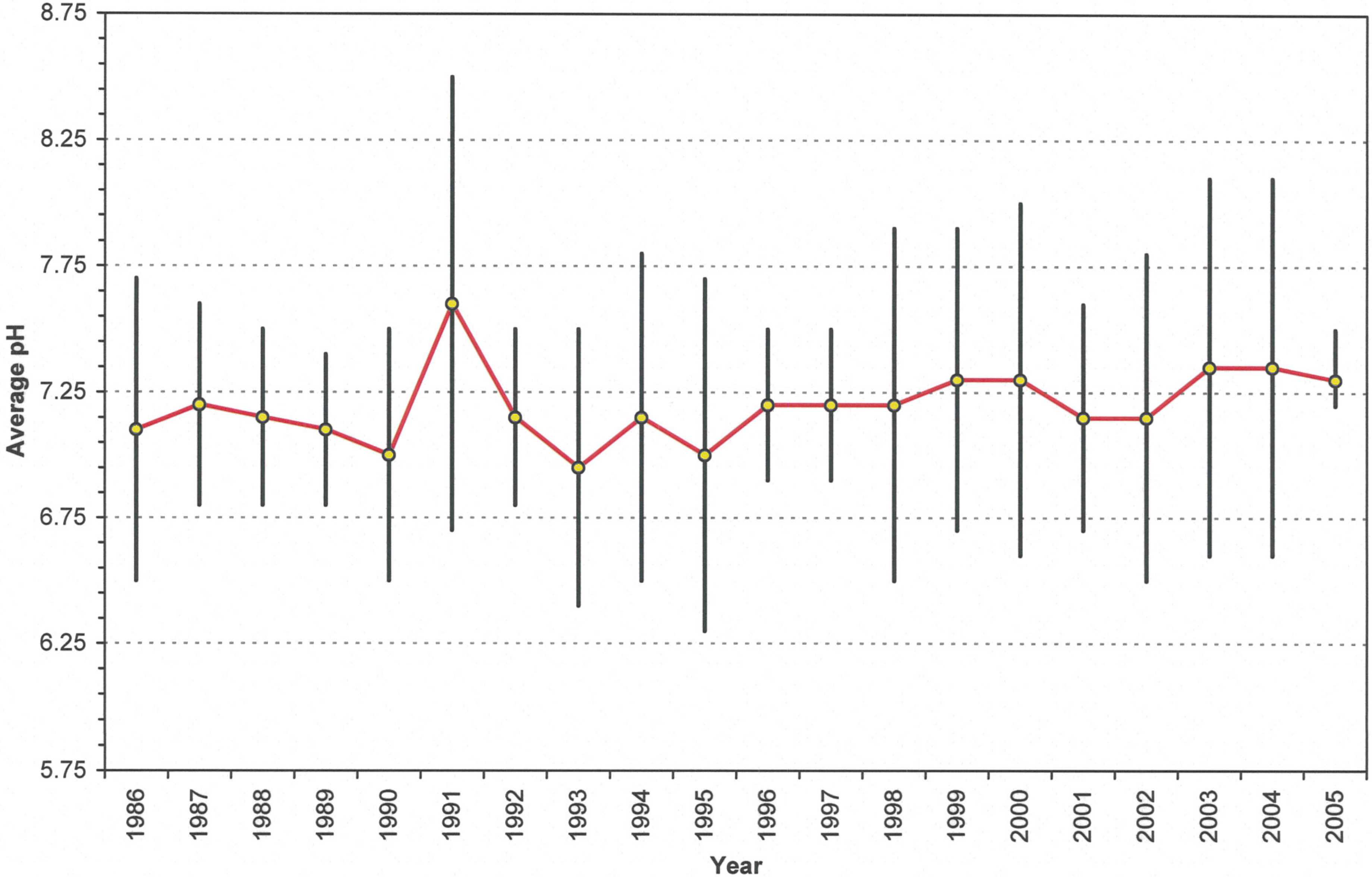


Figure 8. Annual Averages and Range of Effluent DO Concentrations for the Asplund WPCF - 1986 to 2005

Figure 9. Annual Averages and Range of Effluent Temperature (°C) for the Asplund WPCF - 1986 to 2005

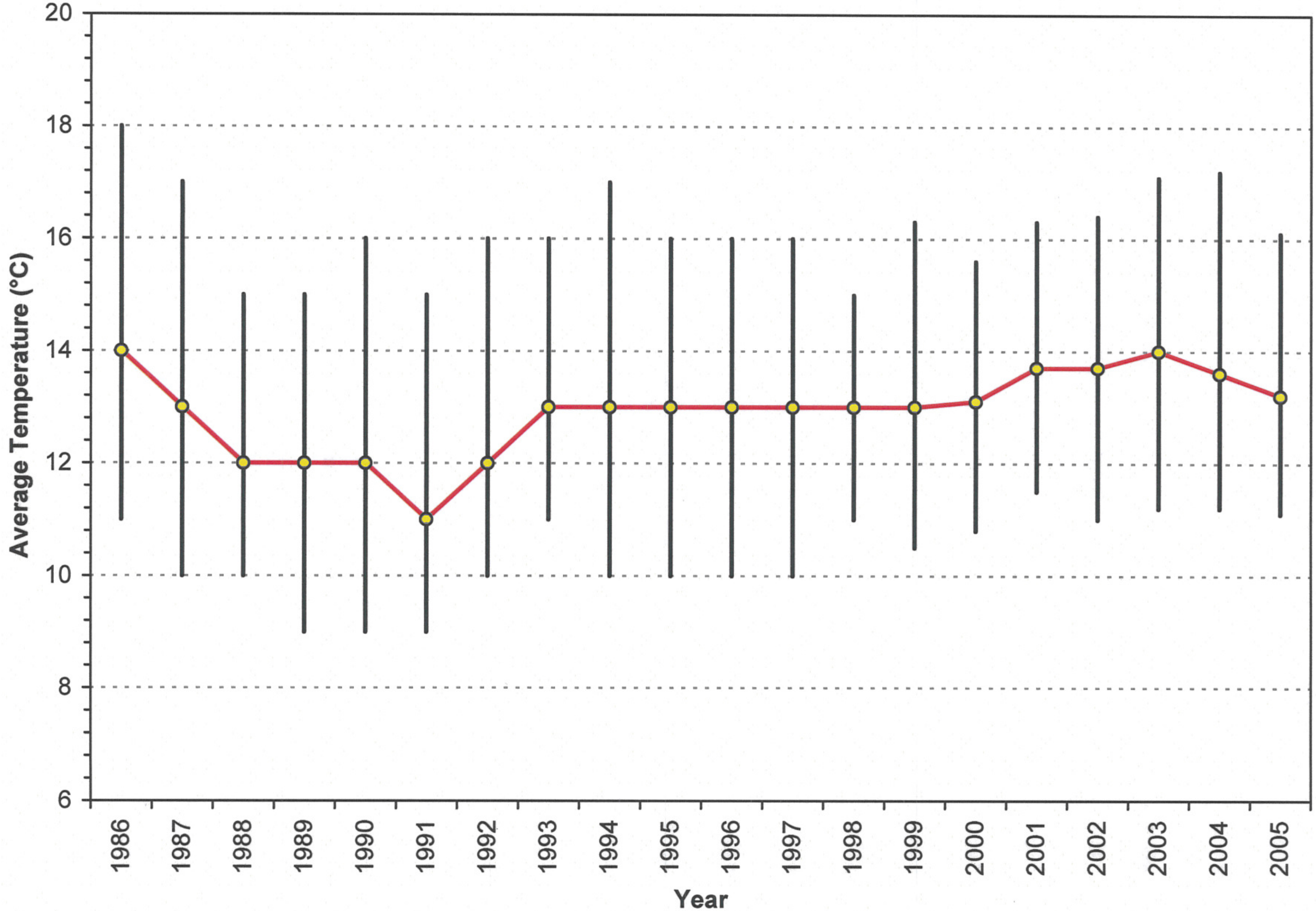


Figure 10. Annual Averages and Range of Effluent Fecal Coliform Bacteria for the Asplund WPCF - 1986 to 2005

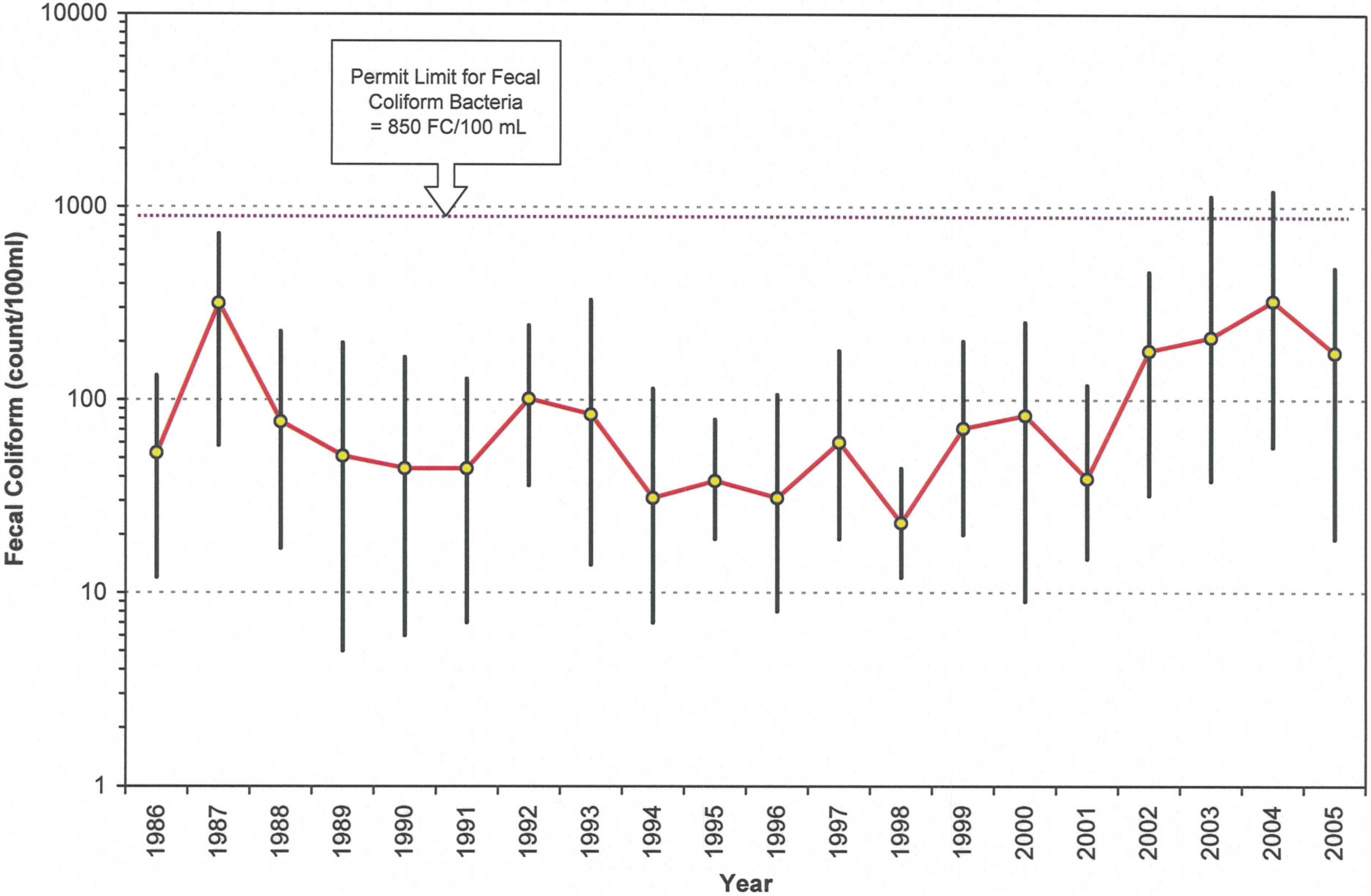


Figure 11. Annual Averages and Range of Effluent Total Residual Chlorine Concentrations for the Asplund WPCF - 1986 to 2005

**Figure 12. Annual Average Effluent Total Metal Concentrations of Arsenic, Beryllium, Cadmium, Chromium, Copper, and Cyanide for the Asplund WPCF - 1986 to 2005**

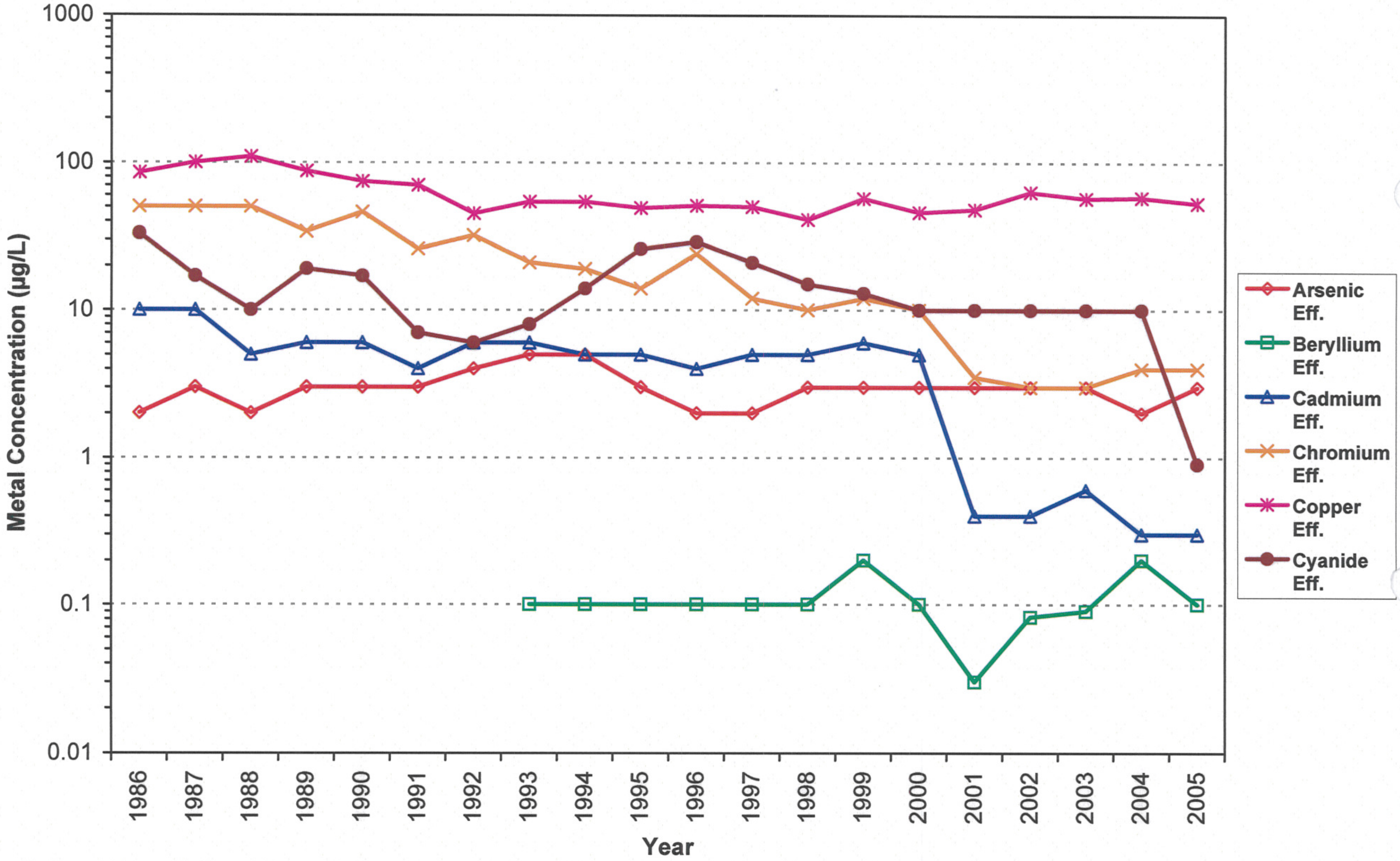


Figure 13. Annual Average of Effluent Total Metal Concentrations for Lead, Mercury, Nickel, Silver, and Zinc for Asplund WPCF - 1986 to 2005

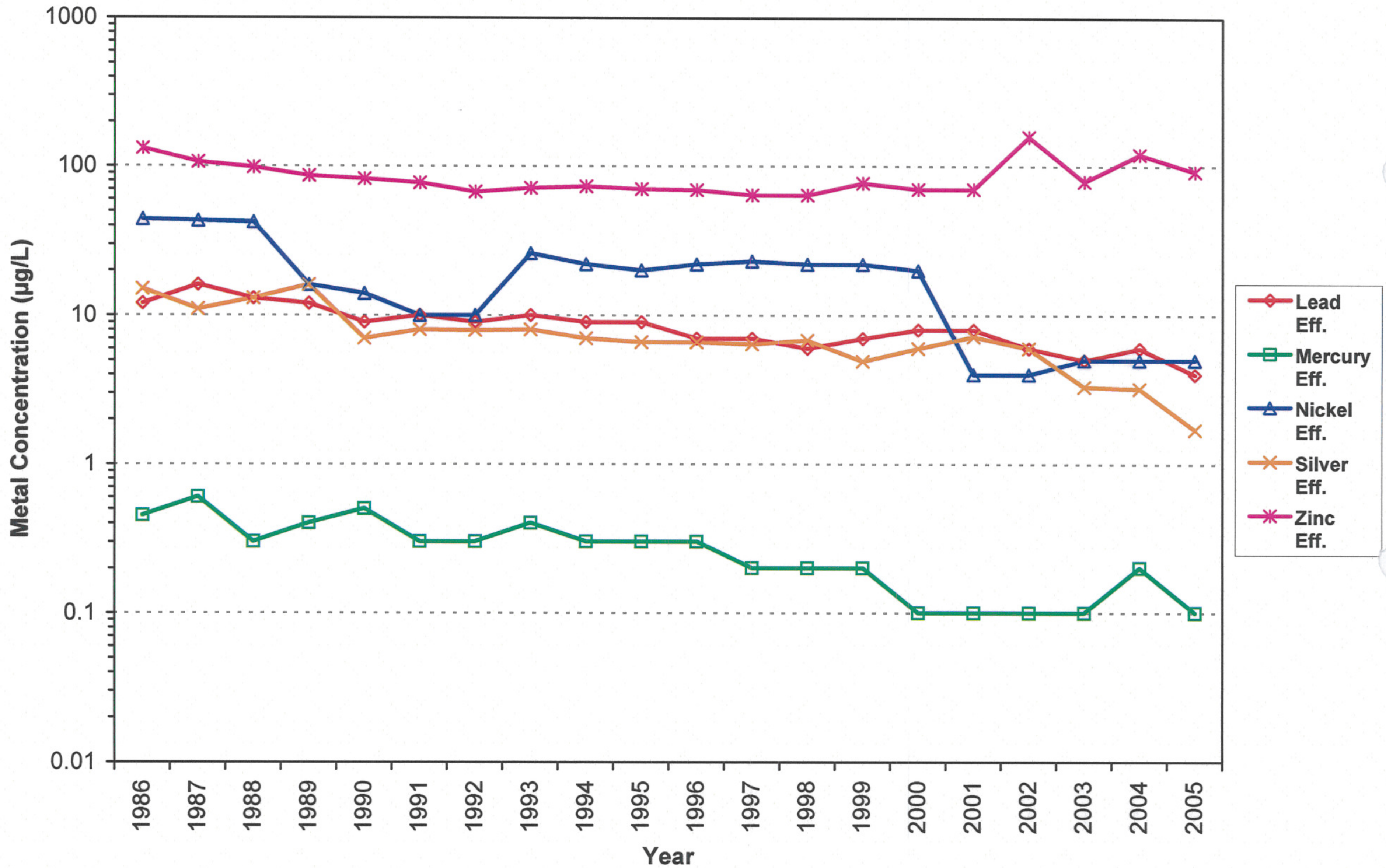
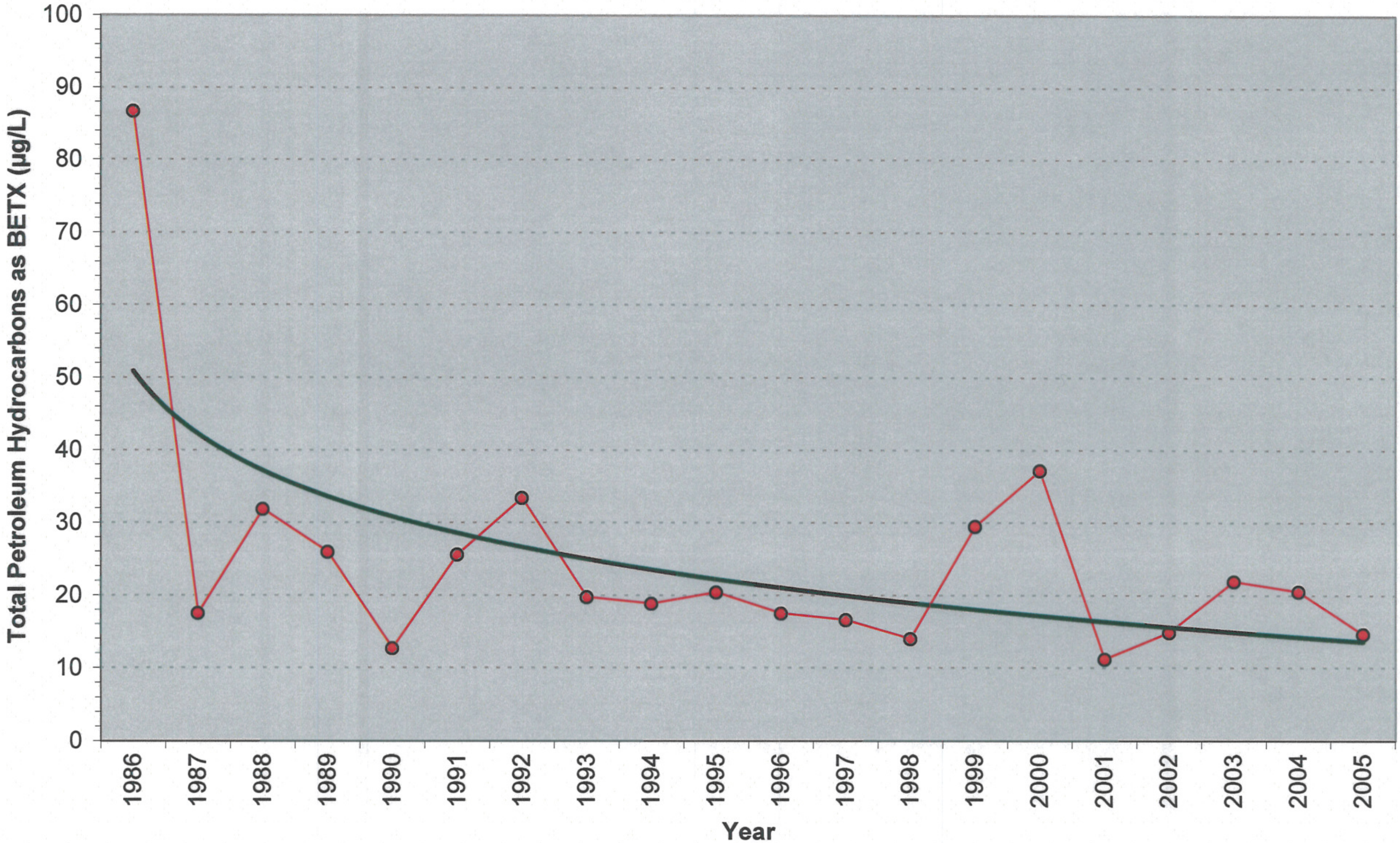
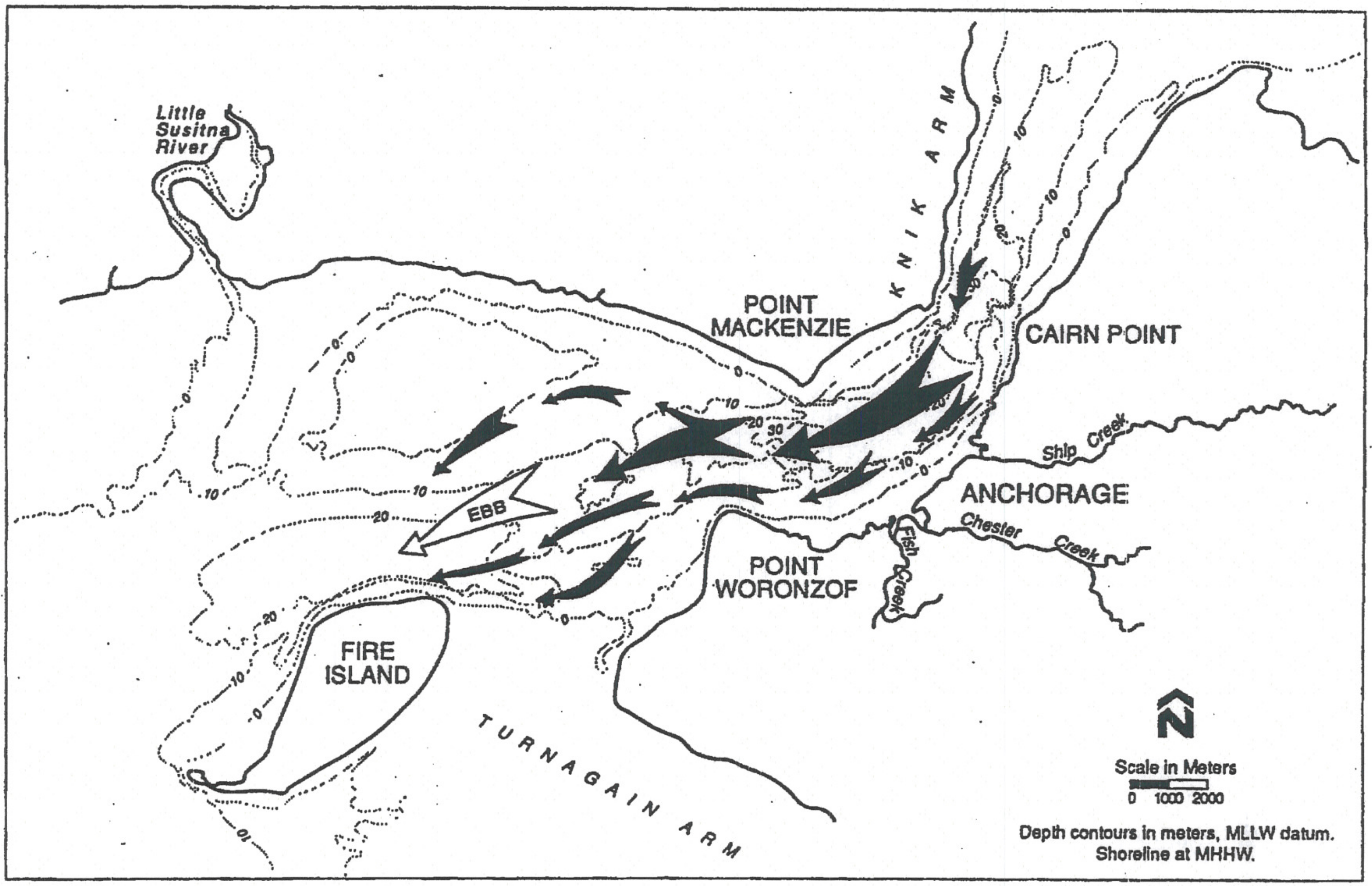


**Figure 14. Annual Averages and Long-term Trend of Effluent Total Aromatic Hydrocarbons (as BETX) for the Asplund WPCF - 1986 to 2005**

(NDs are defined as zero)

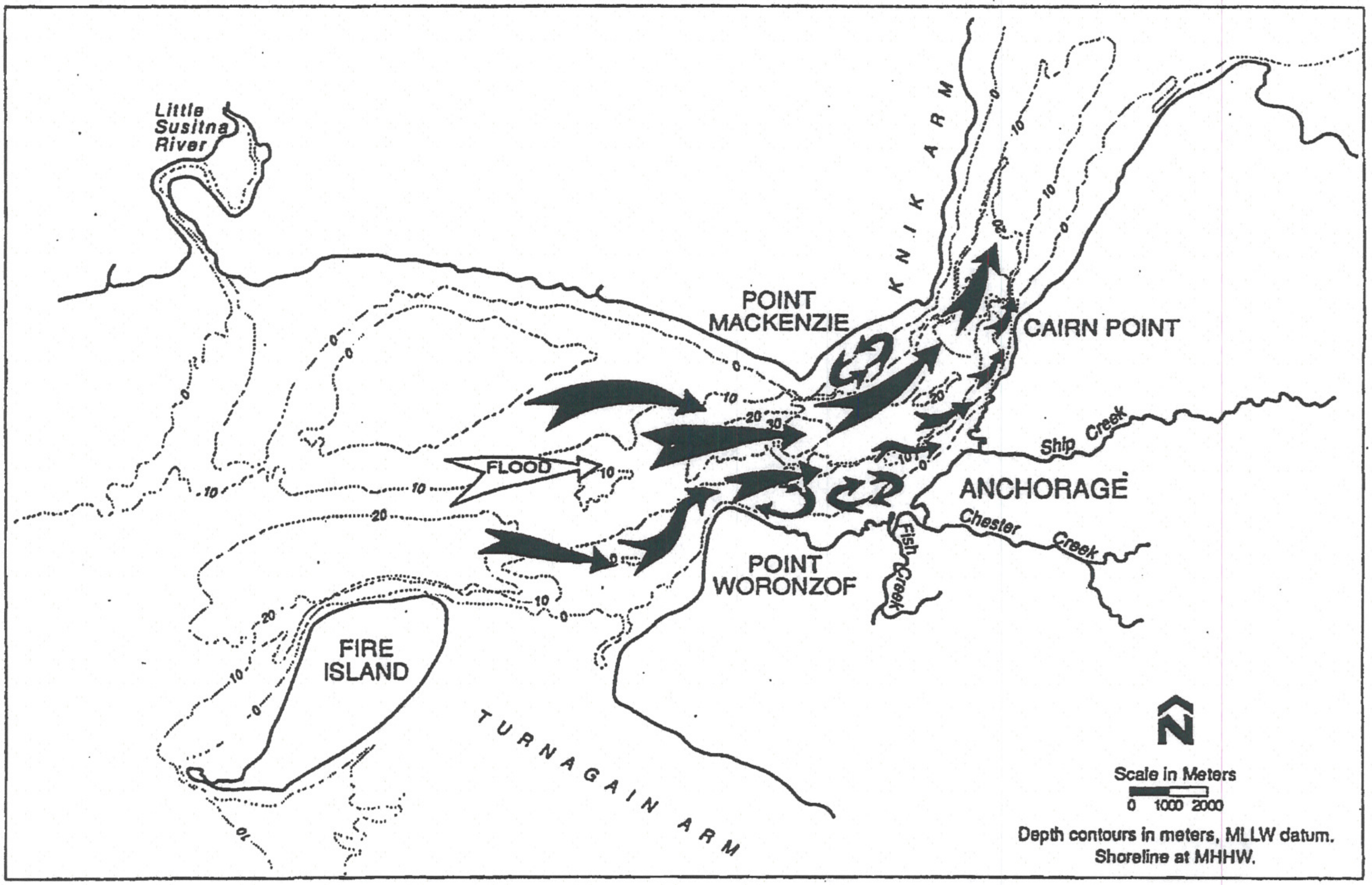





Note: Size of current vector indicates the relative strength of the current.

**Figure 15**

**Generalized Current Pattern at Point Woronzof During Ebb Tides**




Note: Size of current vector indicates the relative strength of the current.

**Figure 16**

**Generalized Current Pattern at Point Woronzof During Flood Tides**

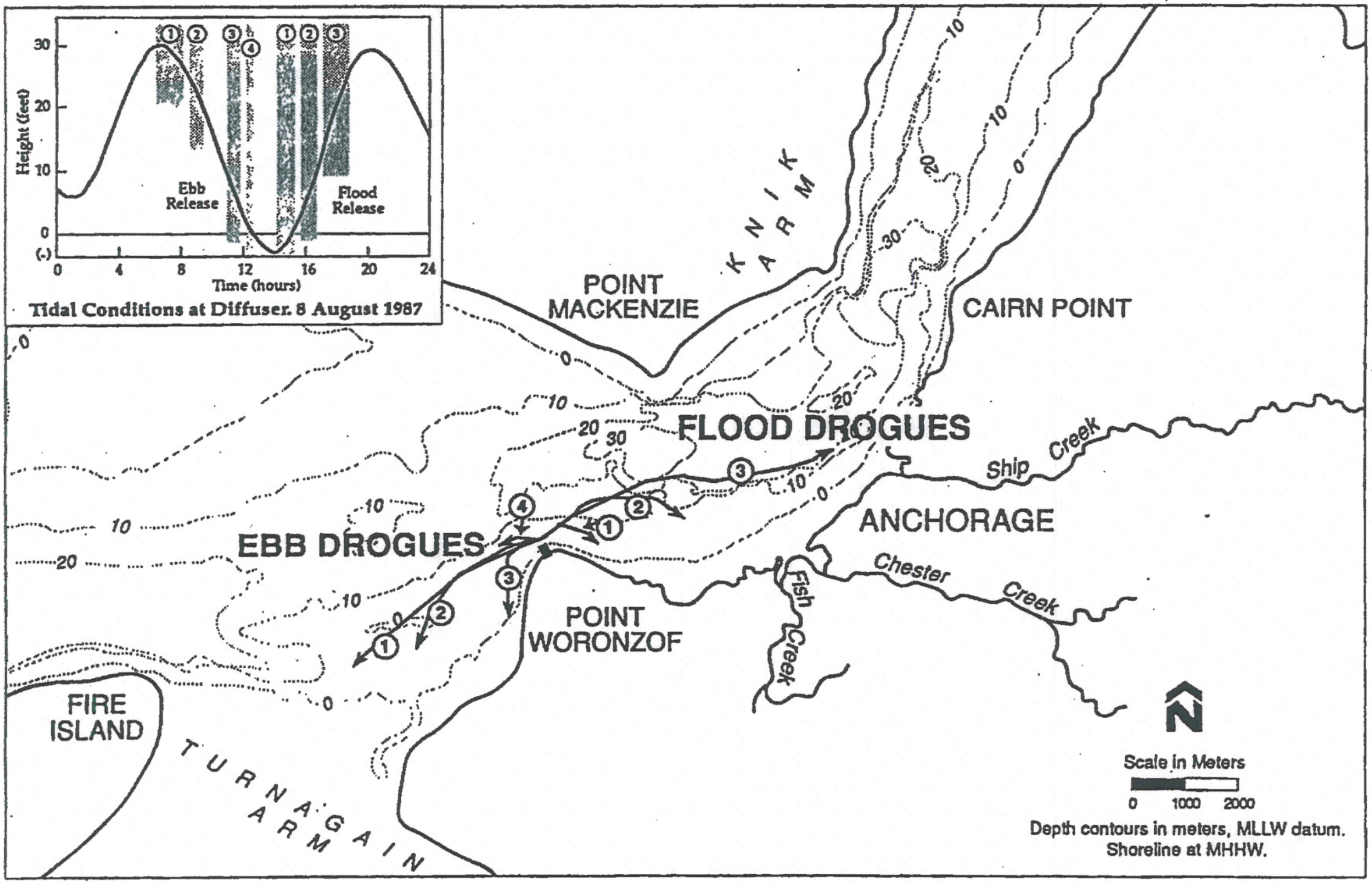



**Figure 17**

**Summary of Flood and Ebb Drogue Tracks at Point Woronzof,**

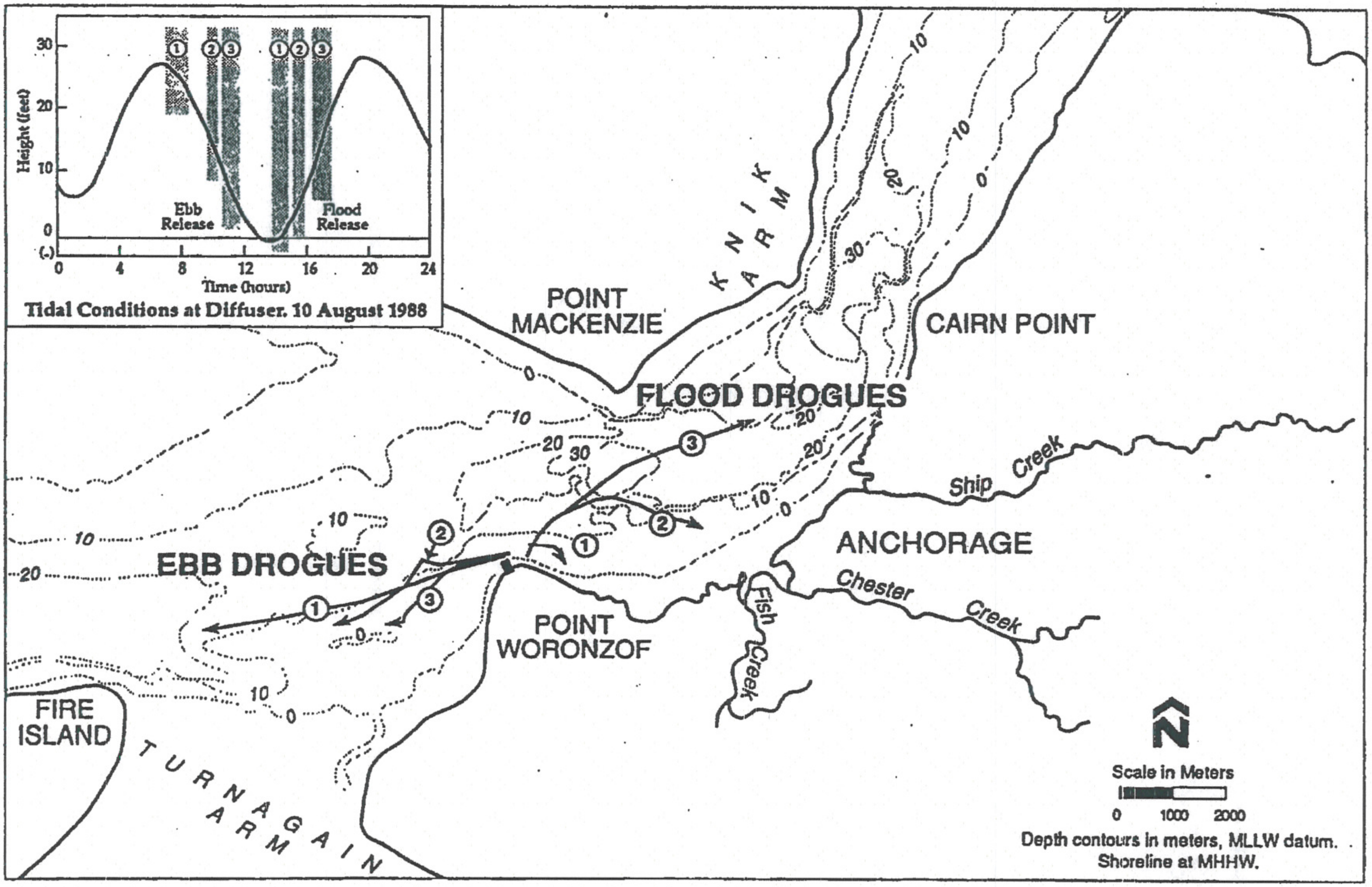



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**Figure 18**

**Summary of Flood and Ebb Drogue Tracks at Point Woronzof.**

106853.A6.ZZ_ei

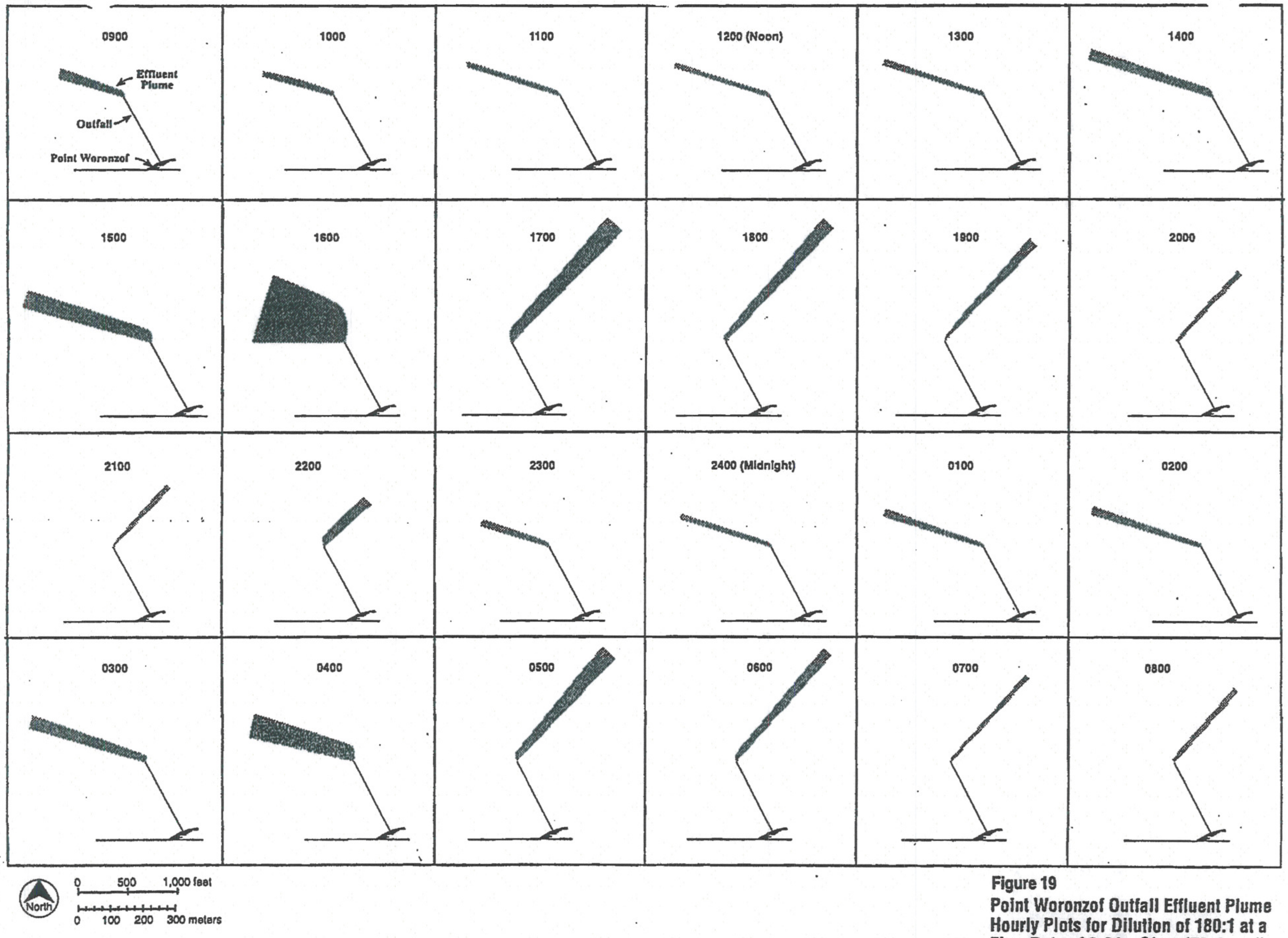


**Figure 19**
**Point Woronzof Outfall Effluent Plume Hourly Plots for Dilution of 180:1 at a Flow Rate of 3.21 m³/sec (73.4 mgd)**

Figure 20. Fecal Coliform Geometric Mean Data Summary for Receiving Water Samples - 1996 to 2005